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Automatic meter reading systems

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AUTOMATIC METER READING SYSTEMS

By

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ABSTRACT

Electric, gas, and water utilities have long dreamed of replacing manual meter reading systems with automatic, remote meter reading systems. Today, several experimental systems have been built which successfully read billing meters at a distance, on a mass basis. None of these systems are presently being used by utilities for actual billing, however. Utility people now wonder when they can justify an automatic meter reading system.

Since utilities vary greatly, this question has to be answered by each individual utility contemplating an automatic meter reading system. Each utility section, which is directly or indirectly involved in the billing cycle, must be examined for tangible and intangible benefits of employing an automatic meter reading system.

Initial costs associated with the purchase and installation of meter reading equipment, as well as new operating costs which will be incurred when the system is installed, must also be estimated. All costs and benefits should be expressed as annual costs and savings per meter in order to provide a basis for comparison.

The cost of equipment is very critical to the economic success of an automated meter reading system. For this reason, automatic meter reading system functions and components must be studied, in detail, and an optimum system configuration selected.

Though experimental automatic meter reading systems vary considerably in makeup, each system contains several basic elements which comprise a generic automatic meter reading system. Basically, these elements are 1) the meter/encoder, 2) the meter data set/coupler,

3) the meter reading data channel, 4) the interface/decoder, and 5) the meter reading data compiler.

A detailed analysis of experimental meter reading systems, in terms of the generic components, has lead the author to conclude that systems which employ ordinary telephone lines as the meter reading data channel are more economical than systems which depend upon power lines, pilot wires, or radio for communications. This conclusion, however, is based on the assumption that the American Telephone and Telegraph Co., which supplies about 80% of the telephone service in the United States, will soon file for a new, lower monthly charge tariff with the F.C.C. specifically for automatic meter reading.

CHAPTER ONE
INTRODUCTION TO AUTOMATIC METER READING SYSTEMS

(11, 12, 13, 14, 17, 19, 24, 26, 27, 29, 32, 33, 38, 53)

Electric, gas, and water utilities are government regulated companies which supply useful products to the public on a continuous basis. Within certain limits, the amount of product used by each utility customer over a fixed period of time is variable and best measured at the customer's site. Accurate meters have been developed to measure kilowatt hours of electric energy and cubic feet of gas and water at customer locations. These meters are read periodically by utility personnel and customer bills are prepared on the basis of actual usage and predetermined rates.

Billing Cycle

The recurring process of reading meters and billing customers is called a billing cycle. A generalized billing cycle involving several utility sections is shown in Figure 1. The cycle starts when the Customer Accounting Section sends consumer books to the Meter Reading Section with instructions to take readings. The Meter Reading Section dispatches meter readers to customer locations specified by the Customer Accounting Section. After the readings are taken, the Meter Reading Section collects the consumer books and sends them to a Checking Section which looks for obvious errors in meter reading data. The Checking Section then sends the checked meter reading data to the Keypunching Section. The Keypunching Section prepares punched cards from the consumer books, sends the punched cards to the Sorting and Merging Section, and returns the consumer books to the Customer Accounting

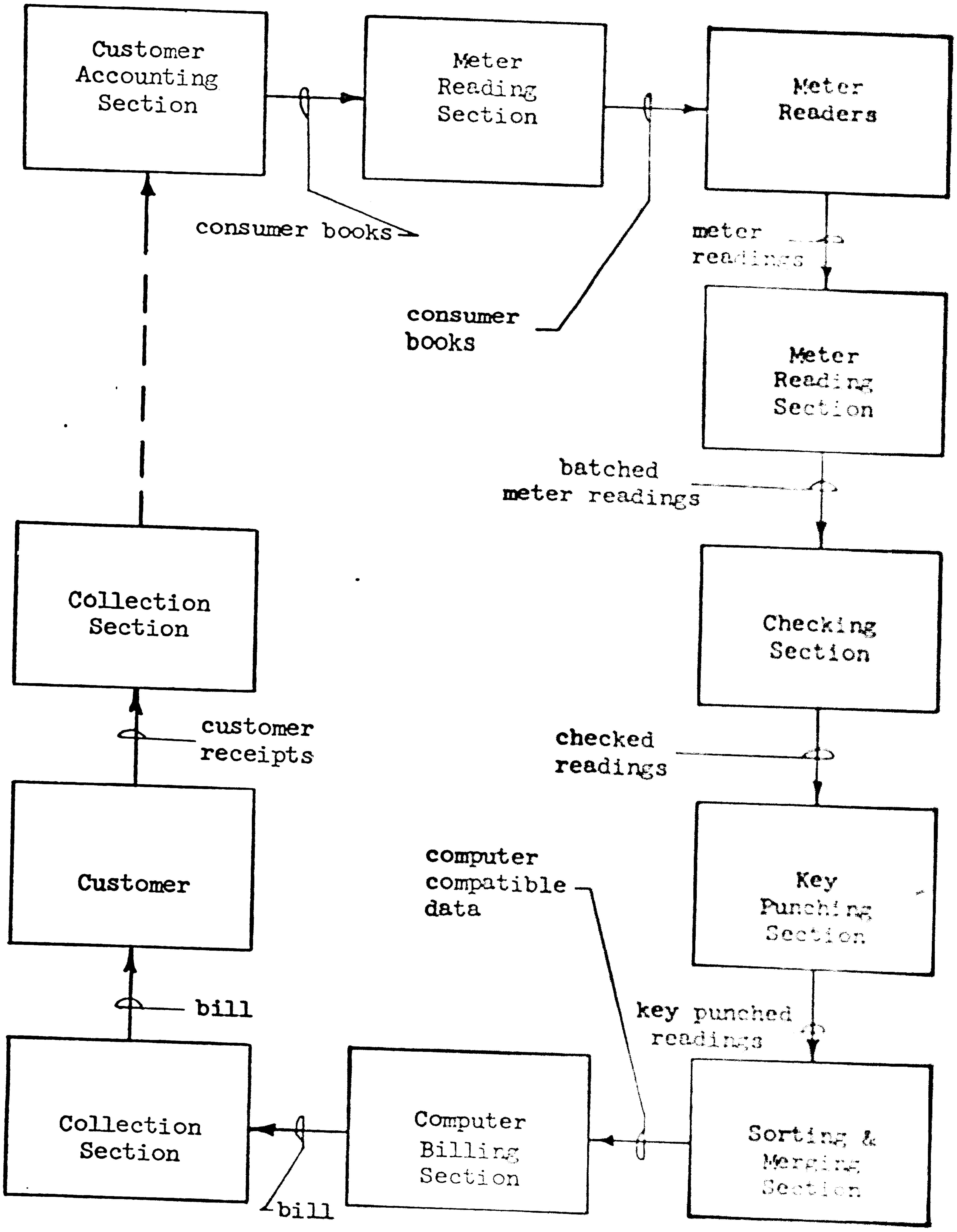


Figure 1
Generalized Billing Cycle

Section. The output of the Sorting and Merging Section is computer compatible meter reading data which the Computer Billing Section uses to prepare consumer bills. The Collection Section receives the prepared bills from the Computer Billing Section, sends the bills to utility customers, and collects cash receipts from the utility customers.

Although individual utilities vary in degree of billing cycle sophistication, a very significant part of the operating costs of all utilities is attributable to the periodic manual reading of meters and billing of customers. Automatic meter reading (AMR) systems are electronic systems which reduce or eliminate some of the expenses associated with the billing cycle by reading customer meters remotely.

Billing Cycle with an Automatic Meter Reading System

The basic operation of an automatic meter reading system can best be understood by again referring to the utility billing cycle. A generalized billing cycle for a utility using an AMR system is shown in Figure 2. As before, the cycle starts when the Customer Accounting Section requests the Meter Reading Section to acquire current customer meter data. Instead of dispatching meter readers to take manual readings at customer locations, the Meter Reading Section initiates the automatic, remote reading of customer meters using AMR equipment located in the utility office or in an interrogation van or craft. The meter data compiled by the AMR equipment can be made to be computer compatible and, therefore, it can be used directly by the Computer Billing Section. Since most utilities have a well automated Computer Billing Section, no change will occur in the operation of this section when an AMR system is

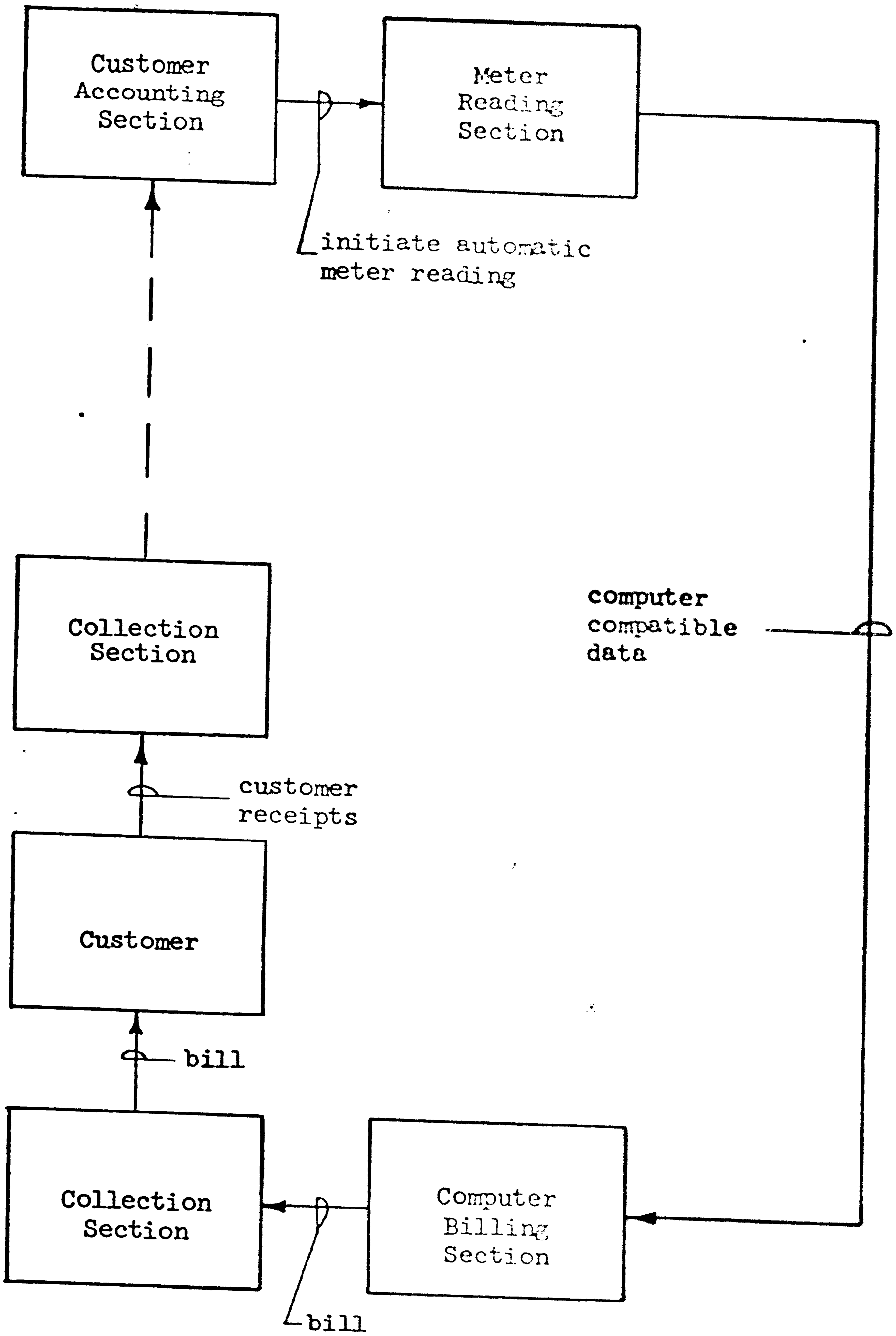


Figure 2
<u>Generalized Billing Cycle with Automatic Meter Reading</u>

employed. The functions of the Collection Section will, likewise, be the same as those under the conventional billing cycle.

Purpose of Thesis

Several experimental AMR systems have been built which successfully read billing meters at a distance, on a mass basis. None of these systems are presently being used by utilities for actual billing, however. Utility people now wonder a) when they can justify an automatic meter reading system and b) what hardware configuration represents a practical, economical automatic meter reading system.

In answer to these questions, this thesis:

(1) Establishes a criterion which will allow individual utilities to determine the economic feasibility of an automatic meter reading system, and

(2) Identifies an optimum automatic meter reading system by analyzing the components and functions of several prototype systems.

CHAPTER TWO
ECONOMIC FEASIBILITY OF AN AUTOMATIC METER READING SYSTEM

A comparison of Figures 1 and 2 indicates that there is a reduction in the number of company sections needed in the billing cycle when an AMR system is used. The savings obtained by using an AMR system are, however, greater in number than those implied by this simple comparison. Each utility interested in the feasibility of using an AMR system must scrutinize each company section which is directly or indirectly associated with its' particular billing cycle. In each section studied, the annual cost saving per meter should be estimated and intangible benefits noted. The following advantages should be considered when making this study.

(a) Customer Accounting Section

Billing with an AMR system is feasible every month instead of bimonthly. This results in a greater cash flow for the utility. Considering the time value of money, this cash flow means added revenue for the company.

Off cycle billings and manual rebillings due to meter reader misreads or skipped readings are eliminated. Customer Accounting Section clerical and supervisory personnel and associated overheads may be reduced accordingly.

(b) Meter Reading Section

Since meter readings can be taken without the aid of a meter reader, the meter reading force can be reduced 90 to 100% to a few individuals who will handle complaint readings and check erroneous readings. Expense reductions include direct meter reading labor and associated overheads such as allowed time off, pensions, and payroll taxes; associated expenses such as transportation, travel expenses, office space rental, office equipment, office supplies; and meter reader supplies such as meter books, uniforms, foul weather gear, hats, meter seals, tools, dog repellents and identification badges. There will also be a slight reduction in the overall Meter Reading Section supervision because of a reduction in local supervision of meter reading forces. The net result will be a reduction in the supervision in the order of 25%.

Because the meter reading force will be reduced to a skeleton force, the cost of training new meter reader personnel will be reduced drastically. Training costs are quite significant since there is a high rate of turnover in the meter reader job classification. The turnover rate is estimated to be as high as 50% per year with some utilities. Some utilities are forced to carry on with 70 to 80% of their needed personnel in the Meter Reading Section because of the relative unattractiveness of the meter reader position. Meter reader positions are generally unrewarding, low paying jobs which attract some "problem" personnel. Many of those now employed as meter readers can be retrained for jobs requiring greater skill and affording greater interest and compensation.

Costly hazards, obstacles and inconveniences associated with manual meter reading will be eliminated when an AMR system is adopted. Utility personnel will not have to take meter readings in troubled, unsettled neighborhoods. Some districts are extremely dangerous, requiring two or more men to make a reading. Vicious dogs and attacks by customers mistaking meter readers for housebreakers will be ended.

Injuries, when they occur, are very costly to the operation of a utility and extremely bad for employee morale.

Foul weather does not prevent an AMR system from making readings. Manual meter reading documents are often damaged due to inclement weather; this problem will not exist with an AMR system.

Indoor meters are found quite commonly in dense urban areas where outside wall space is at a premium. In such areas meter reader lockouts are frequently experienced. Many married women are "working" wives these days increasing the probability that no one will be home when the meter reader requires access to the inside meter. Due to the changing life style of the typical American family, non-working women are away from home an increasing amount of time during the day. Repeated calls are sometimes needed to make a single meter reading; Regulatory Commission rulings generally permit only two or three estimated bills to be made so readings must be eventually obtained at any cost. Some utilities circumvent the lockout problem by maintaining an inventory of keys. The cost of maintaining this inventory would, in this case, be eliminated by the use of an AMR system.

Manual meter reading in rural areas is very costly because customer meters are spaced a considerable distance apart. Large amounts of time and transportation are required to read rural meters; re-reading rural meters due to missed readings is <u>very</u> expensive. Distance between meters is a nonexistent problem with most AMR systems.

The cost of functions related to routine meter reading will also be considerably reduced with an automated meter reading system. Some AMR systems can provide a ready means for checking questioned readings without sending out a reader. Because readings will be taken by automated equipment, there should be a reduction in erroneous readings. Some AMR configurations can also provide a big savings by allowing customer start and closeout readings to be made from the utility office. In some rental areas, frequent changeout readings are quite common.

Meter readings should be obtained in less time with an AMR system resulting in a three to six day decrease in billing time. Considering the time value of money, based on a national average of $265 in annual revenue per meter (1969 average), an estimated three to six day reduction in billing time, considering interest charges at 7%, a savings of 15 to 30 cents per meter per year would result.

(c) Checking Section

Meter reading forms will not exist with an AMR system. Therefore, the need for a meter reading form review section will vanish. Also disappearing are the Checking Section personnel costs, supervisory costs, and associated overheads.

(d) Keypunching Section

A cost savings can be realized by utilities which keypunch and verify customer meter reading data. The services of the Keypunching Section will not be required for routine meter readings with an AMR system.

Since erroneous readings will be considerably reduced with an AMR system, correction keypunching will also be minimized.

(e) Sorting and Merging Section

Keypunched cards, representing meter data from various company areas, have to be sorted and merged under the manual meter reading system.

With AMR, meters throughout the company can be read in any desired order. Therefore, computer compatible data can be obtained without incurring the costs of the Sorting and Merging Section. When sorting and merging is required, it can be done by computer.

(f) Computer Billing Section

Since missed readings can be practically eliminated with an AMR system, the cost of preparing machine estimated bills and the cost of adjusting subsequent bills will be eliminated.

The reduction of erroneous readings will result in a reduction in the cost of processing off-cycle billings.

Companies which use mark sense sheets for manual meter reading will no longer have to computer prepare these sheets for the meter readers.

(g) Collection Section

An AMR system, coupled with monthly billing cycle, will allow delinquent accounts to be spotted in at least half the time possible with a bimonthly manual reading system. This could reduce the cost of bad debts by 50%.

(h) Customer Relations Section (not shown on Figure 1)

Because bills can be prepared monthly using actual readings instead of estimated readings, the number of complaints about high bills should be substantially reduced when an AMR system is used. Similarly, the reduction in erroneous readings which accompanies AMR system operation will result in a lower number of bill complaints. The clerical, supervisory, and overhead costs of handling bill complaints will decline accordingly.

When bill complaints do occur, the AMR system provides a means for quickly verifying meter readings. A manual entry capability can be included in the AMR system so that particular readings can be checked from the utility office. The cost of personnel, transportation, and overhead associated with manually making meter reading checks at the customer's location can be reduced considerably.

The fact that meters can be read without a meter reader is a good feature from a customer relations viewpoint. There is an increasing fear and resentment by homeowners of the invasion of property by meter readers. This fact is essentially true of all utility customers, regardless of whether customer meters are located inside or outside the residences.

In areas where meters are located outdoors, the utility can save the expense of answering complaints and compensating customers for property damage. Homeowners object to having bushes and flower beds trampled by meter readers.

In areas where meters are located indoors, invasion of privacy becomes undesirable. Three methods are generally employed by utilities to gain access to indoor meters. By the first method, the utility maintains an inventory of duplicate house keys. This system tends to cause a great feeling of insecurity in the minds of the customers. By the second method, the homeowner is required to leave an entrance way close to the meter open on designated days. As with the first method, this procedure tends to make the customer feel uneasy and the meter reader has often been mistaken for a burglar. By the third method, the utility representative is required to announce his presence to the customer and thus interrupt the homemaker's duties. Tracking mud and dirt into the customers' homes is certainly bad for customer relations. Also, the possibility that criminal acts can be performed by persons misrepresenting themselves as utility personnel exists.

Because meter readers are not required with AMR, the cost of handling complaints about meter readers will be eliminated.

(i) Mail Room and Courier Service Sections (not shown on Figure 1)

Mark sense cards or consumer books will not have to be separated by route, packaged, and sent to local Meter Reading Section offices when an AMR system is employed. The return delivery of these forms or books from the meter readers to the central office will also be eliminated.

Auxiliary Functions of AMR Systems

There are several utility functions besides meter reading which can be performed by automatic meter reading system hardware. If auxiliary functions are desired by a particular utility preparing an AMR system cost and benefit study, the worth of these functions per meter per year should be estimated. The worth of each auxiliary function helps to defray the total cost of the AMR system. A description of several auxiliary functions is given below.

(a) Service Restoration

A feature can be incorporated in an AMR system which will allow utilities to scan certain key locations in order to determine which customers are out of service. For electric utilities, this information can be used in a computer system to quickly determine the location of the trouble, the type of device (transformer fuse, line fuse, oil circuit recloser) which caused the interruption, and, if a fuse blew, the size of the fuse replacement. Valuable time and money can be saved by restoring customer service as soon as possible. Gas and water utilities could use this feature to find main or feeder breaks.

(b) Load Survey Studies

An AMR system provides a means to monitor load at selected metering points. This allows the electric utility to make load studies for distribution transformer sizing analysis. All utilities can use load information to make feeder and service load analyses. For large commercial customers, periodic scanning can result in the elimination of demand registers.

(c) Monitoring Interruptible Load Customers

During a gas, water, or electric system emergency, utilities generally ask large load customers to voluntarily curtail or reduce their load until the crisis passes. AMR provides a means to monitor interruptible or reducible load customers in order to check compliance with the utilities request.

(d) Selective Load Shedding

At times it is desirable and feasible to momentarily turn off certain loads during peak load periods without degrading the customer's service significantly. As an example, electric hot water heaters may be cut off on a rotating basis in order to ease an electric utility over peaks. The AMR system provides a means for controlling the load shedding mechanism at each customer's location.

(e) Automatic Service Connect and Disconnect

Provisions can be made with an AMR system to turn on and cut off customer services from the utility office. This feature would save utilities the expense of traveling to the customer sites and manually connecting or disconnecting services.

(f) Distribution System Control

Certain AMR system configurations can provide means to control the distribution system from the utility office. Electric utilities can control switchable capacitors, sectionalizing devices, and street lighting for example.

<u>Capital Costs and Disadvantages of Automatic Meter Reading</u>

Like all new systems, the installation of an automatic meter reading system requires an initial outlay of capital. Once installed, certain operating costs are incurred by the new system. Utilities desiring to determine the feasibility of an AMR system in their company must look at each company section and estimate the annual cost <u>per meter</u> of an AMR installation. The annual carrying charge per meter should be estimated for capital expenditures since the initial cost of an AMR system is large and it will have to be written off over a long period of time. Intangible, detrimental effects of an AMR system should also be recognized. The following costs should be considered in a cost and benefit study.

(a) Meter Section (not shown on Figure 1)

The annual carrying charge per meter for AMR customer meters or meter conversions and for utility labor to install new meters or convert existing meters must be calculated. If new meters are used, the net salvage of the old meters should be considered. The cost per meter per year for meter data transmission equipment and installation labor, supplied by others, must be determined.

The cost of planning and scheduling an orderly change-over to an AMR system has to be looked at. If installations require the cooperation of another company, such as the telephone company, the cost of coordinating the efforts of two companies has to be studied.

The cost of training utility personnel to operate and maintain the AMR system has to be estimated. AMR system preventive maintenance program cost should also be determined.

The cost effect of AMR system downtime has to be considered. The utility cash flow will be interrupted when the AMR equipment fails.

(b) Computer Billing Section

Additional computer, control, and data gathering equipment will be required either at the central computer center and possibly in regional offices or in an interrogation van or craft. The installation and rental cost of this equipment must be estimated.

The annual charge for attaching each meter to a foreign utilities communications network and using a portion of the foreign utilities facilities for data gathering must be determined.

The cost of purchasing or leasing dedicated communication lines must be estimated. Dedicated lines may be used for other computer applications thus defraying the cost attributable to an AMR system.

The cost of processing bills monthly instead of bimonthly has to be included in this study.

(c) Collection Section

Monthly billing may require twice as much clerical work as billing bimonthly. If monthly billing is adopted in conjunction with the installation of an AMR system, the additional cost of clerical and supervisory help plus overheads should be included.

(d) Customer Relations Section (not shown on Figure 1)

The meter reader is viewed by some as being the last human link between utilities and their customers. Eliminating the meter reader will mean that the customer may go for years without seeing a human face representing the utility.

The manually read meter has gained customer acceptance over the years. Remotely read meters will require new acceptance.

Basic Economics of Automatic Meter Reading Systems

After dollar estimates have been made, per meter per year, for the operating savings, the worth of auxiliary functions, the carrying charge for capital expenditures, and the additional operating expenses due to AMR, the feasibility of an automated meter reading system for a specific utility can be determined. A comparison of the total annual AMR benefits per meter (total annual operating savings per meter plus total annual worth of auxiliary functions per meter) to the total annual costs per meter (total annual carrying charge per meter plus total annual additional operating costs per meter) will tell a utility whether an AMR system is feasible at this time.

The cost of utility labor will continue to rise each year. The cost of an automatic meter reading system will, however, decrease and then stabilize in time due to improved technology. If, for a specific utility, the benefits of an AMR system are not equal or greater than the cost of an AMR system, that utility should project its costs in order to determine which point in time an AMR system will be needed. Figure 3 illustrates such a projection.

As shown in Figure 3, one AMR system could serve the needs for two or three utilities. Each participating utility would then share the cost of the AMR system. An alternative is to have a bonded, independent data processing organization read water, gas, and electric meters for the utilities.

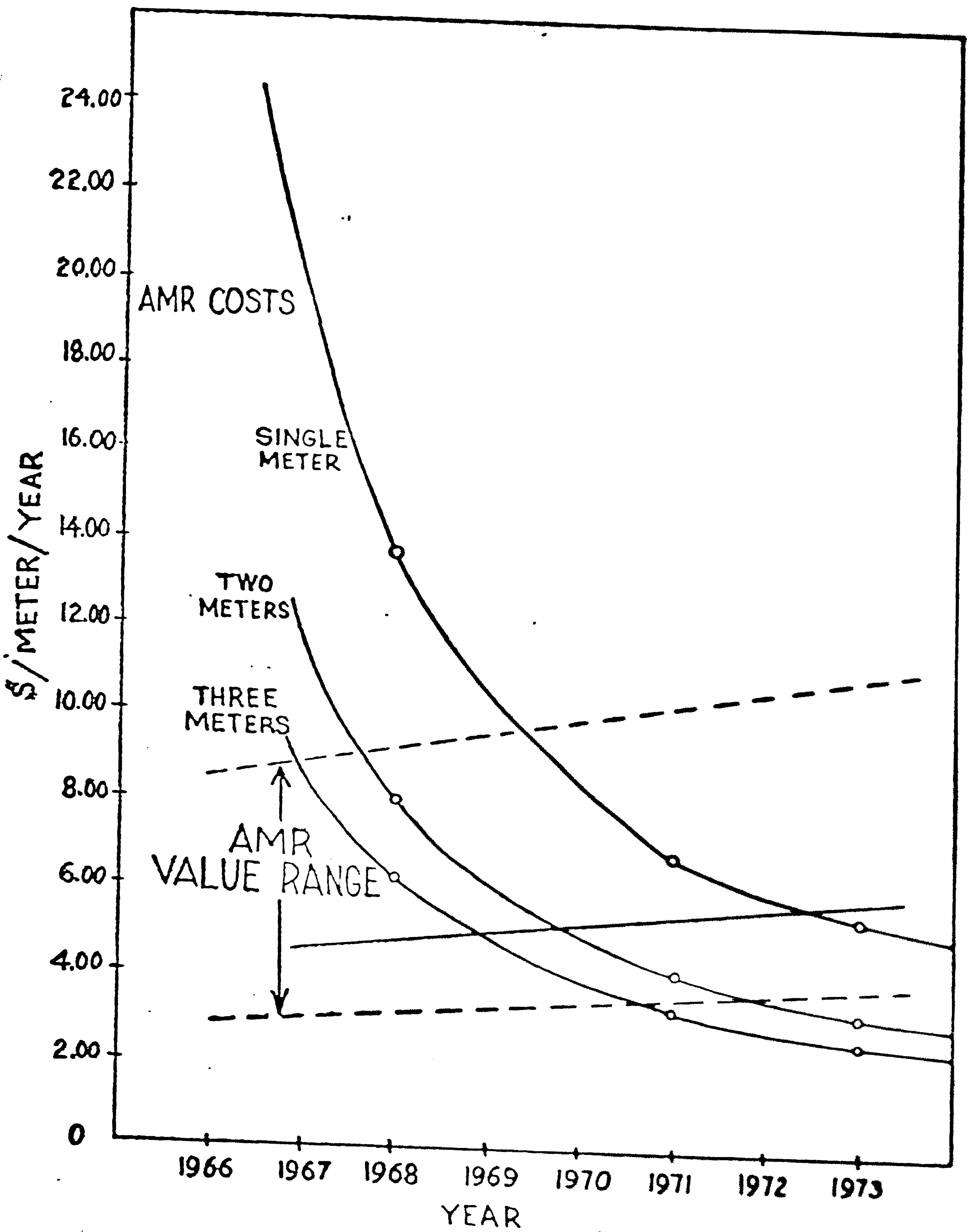


Figure 3
Automatic Meter Reading Economic Trends
(General Electric)

CHAPTER THREE
GENERIC AUTOMATIC METER READING SYSTEM

The cost of equipment is very critical to the economic success of an automated meter reading system. For this reason, automatic meter reading system components and functions must be studied, in detail, and an optimum system configuration identified.

Although many variations and combinations of hardware can be used to read meters automatically, there are several basic elements found in every automatic meter reading system configuration. These basic components, which comprise the generic automatic meter reading system, are shown in Figure 4 and described below.

Meter/Encoder

The meter/encoder is a device which measures and encodes customer usage data, on a continuing basis, in a form that can be read by an automatic meter reading system. A meter/encoder is physically located at each utility customer service entrance point.

Meter Data Set/Coupler

The meter data set/coupler is a device which couples the meter/encoder to the meter reading data channel and transmits encoded usage data over the meter reading data channel upon request from automatic meter reading system control equipment. Like the meter/encoder, one meter data set/coupler is located at each customer location.

Meter Reading Data Channel

The meter reading data channel is the media over which encoded meter reading data and AMR system control signals are communicated.

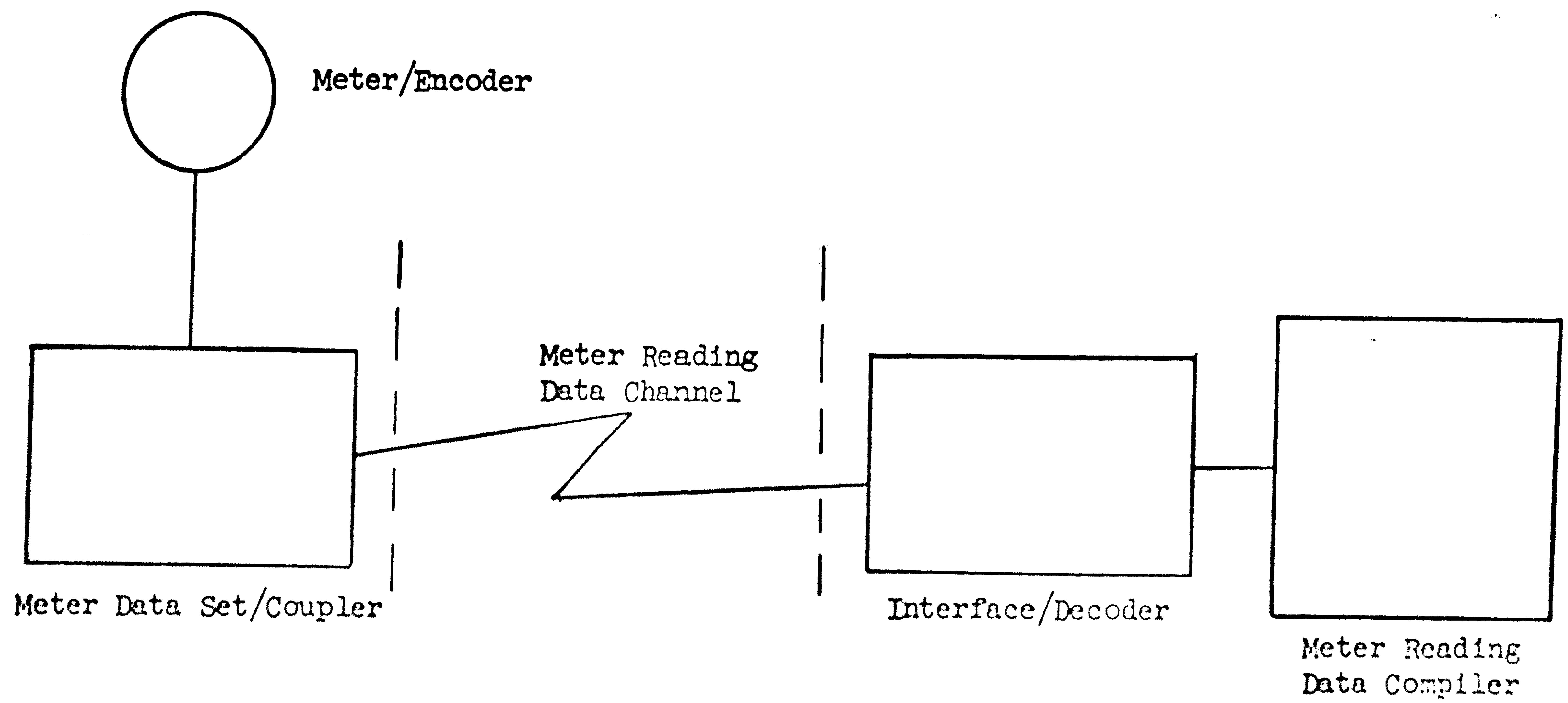


Figure 4

<u>**Generic** Automatic Meter Reading System</u>

Interface/Decoder

The interface/decoder is a device which receives encoded meter reading data over the meter reading data channel and converts the encoded readings into a form that can be used by a meter reading data compiler. This device commonly transmits AMR system control signals over the meter reading data channel to customer meter installations. Physically, the interface/decoder is located on the utilities premises, or in an interrogation van or craft.

Meter Reading Data Compiler

The meter reading data compiler remotely collects meter reading data from customer meter installations. The data compiler generally controls the operation of the AMR system and assembles meter reading data in a form which is compatible with the needs of the utility billing computer. This component of the AMR system is, likewise, located on the utility premises, or in an interrogation van or craft.

The chapters which follow contain an analysis of the different methods employed by AMR system manufacturers to implement the generic components. A description of complete AMR systems, in terms of their generic components, is found in the Appendix of this paper.

CHAPTER FOUR

METER/ENCODER

(3, 11, 12, 15, 16, 18, 21, 22, 24, 26, 27, 32, 33, 39, 47)

Since one meter/encoder is needed for each utility customer, the cost of the meter/encoder must be as low as possible. On the other hand, the meter/encoder has to be accurate, reliable, easy to install, and virtually maintenance-free. These conflicting features require that prudent engineering compromises be made in the areas described below.

Meter Portion of Meter/Encoder

Two types of meter/encoders can be used in an automatic meter reading configuration. The first type of meter/encoder utilizes modified, existing mechanical meters for gas and water applications and modified, existing, hysteresis motor type, electro-mechanical meters for electric customers. The encoder portion of the meter/encoder usually consists of solid state circuitry.

The second type of meter/encoder, which is primarily applicable to electrical metering, uses a solid state meter and encoder. The operation of the solid state meter is generally based upon the equation for power, i.e., current x voltage x power factor. Within the meter, the factors in the power equation are measured and converted to a variable frequency signal which increments a digital counter representing KWH. The frequency of the incrementing signal is directly proportional to KWH.

The advantage of the first type of meter/encoder lies in the fact that existing mechanical and electro-mechanical meters are highly reliable and have a proven life of at least 30 years. Among utility customers, present meters have earned a good reputation and trust.

The methods used in measuring KWH using state circuitry have not been standardized. Consequently, few solid state meter/encoder manufacturers have the same interchangeable design. The reluctance of most utilities to lock themselves to a single meter/encoder supplier is a point against solid state meters.

Altering existing meters instead of adopting solid state meters solves the problem of what to do with the existing meters. Also, the retention of original meter registers satisfies existing regulatory Commission requirements.

Solid state watt-hour meters, on the other hand, have some great advantages over electro-mechanical meters. The solid state meters have no moving parts and may, therefore, be mounted in any position. Since the need for readout dials is practically nonexistent, the solid state meters may be encapsulated to provide exceptional reliability and long life. The encapsulated meter/encoders may be mounted in underground distribution centers, between building studs, or in any convenient location. The size of the meter/encoder can also be made much smaller than present meters.

Technological advances in medium-scale and large-scale integrated circuitry will make the cost of solid state meter/encoders decrease in the future. A point will be reached where, in the event of failure or damage, the meter encoder can be economically discarded, thus eliminating the need for a meter repair shop. The cost of periodic calibration and overhaul can also be eliminated by periodically testing the solid state meters and discarding poor units.

Encoding Methods

Basically, there are two different methods of encoding water, gas, or electricity usage. For discussion purposes, these methods shall be referred to as Method 1 and Method 2.

Method 1 - In the first method, fixed increments of usage are encoded as the change in state of a circuit element or value having two stable states. The remote AMR system keeps a running total of usage by interrogating the bi-stable device frequently (once every hour, e.g.) and checking whether the state has changed since the previous interrogation. If a change occurred, a value equal to the fixed increment of usage is added to the customer's total usage. If no change occurred, the customer's total is not altered.

Method 2 - In the second method, usage is measured and stored, on a continuous basis, in a coded form at the customer meter. The storage element is interrogated periodically, but infrequently (once per month, e.g.) by the remote AMR system.

Although Method 2 encoders are more common, Method 1 encoders can be used very successfully in an AMR system. The main advantage of using a Method 1 encoder lies in the simplicity of the encoding element. A simple mechanical switch or electronic flip-flop circuit which changes position when a predetermined amount of gas, water, or electric energy is used will suffice as the encoder. Considering the great number of utility meters in use, this simplicity can result in a great cost savings. For the METRAGYR system, Landis & Gyr, Inc. uses a mechanical switch which changes position when a fixed quantity of electric energy or gas is consumed.

The detrimental aspect of a Method 1 encoder is, of course, the requirement that the encoder be interrogated often. A Method 1 encoder limits the selection of data channels to dedicated communications paths. Also, a large amount of on-line storage is required since the AMR system must keep a running total for each customer meter.

Method 2 Encoders for Conventional Meters

There are two different types of Method 2 encoders for conventional meters. They are the (a) dial position reading encoder and the (b) pulse counting encoder.

Dial position reading encoders use the original dial mechanism or an auxiliary dial mechanism as the usage storage element. Encoding then consists of electrically determining the position of each dial. A fixed number of parallel leads are read simultaneously by the meter data set coupler when a meter reading is taken.

An example of this technique is the encoder manufactured by McGraw Edison for its ARMETER system. The encoder, shown in Figure 5, consists of two auxiliary discs connected to the meter register "units" drive shaft. The discs each have sixteen teeth and are connected such that one revolution of the "units" drive shaft causes a 1/16 revolution of the "Alpha" disc and one revolution of the "Alpha" disc causes a 1/16 revolution of the "Beta" disc. Each disc has eight holes in its face

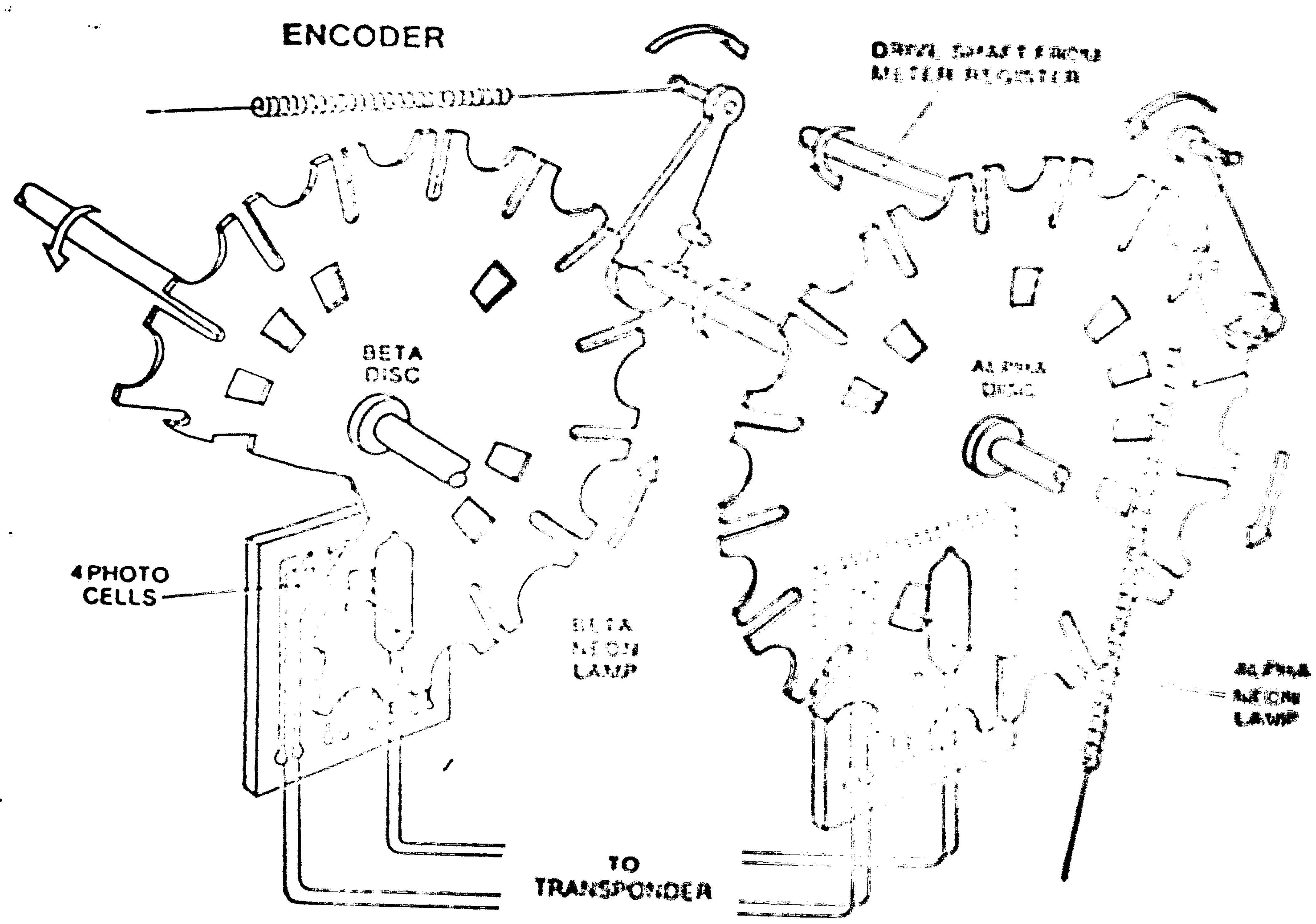


Figure 5

Dial Position Reading Encoder Using Auxiliary Dials
(McGraw Edison, Inc.)

placed such that the 16 positions of each disc can be determined by placing a neon bulb on one side of each disc and an array of four photo cells on the other side of each disc. The photo cells act as switches which are "read" by the meter data set/coupler.

Pulse counting encoders all but ignore the existing dial mechanism as a storage device. With a pulse counting encoder, an auxiliary, external, counting register is incremented by a switch connected to the mechanical or electro-mechanical meter. Much like a Method 1 encoder, the switch in the modified meter pulses the external counter each time one unit (or ten units) of gas, water, or electric energy has been consumed. Frequently, usage is stored in binary or binary coded decimal form in a digital counter register.

The switch arrangement used in the modified meter may be as simple as a single pole, double throw, sealed reed switch and a permanent magnet connected to the "units" shaft of the dial register. The Westinghouse T-COM system uses such an initiator.

Alternately, for watt-hour meters, the number of revolutions of the meter disc may be counted photoelectrically by a precounter. When the precounter counts a number of revolutions equal to the watt-hour constant of the meter, the precounter resets to zero and increments a kilowatt-hour accumulator by one. Such a technique is employed by North American Research Corporation in their UMRARS system.

Dial position reading encoders are simpler than pulse counting encoders and, therefore, more economical. Pulse counting encoders, however, allow greater versatility in adapting existing meters. Any reading measurable by a series of contact closures can be encoded.

Installing a pulse initiator requires less meter modification than installing a dial reading encoder. Also, the number of leads between the meter/encoder and the meter data set coupler are fewer with pulse counting encoders. Three wires are generally required to connect the initiator to the encoder register. Therefore, the installation time of the encoder is apt to be less with a pulse counting encoder.

Using a three-wire contact for the meter initiator allows isolation of the encoder from the meter to give much better design parameters. External encoder registers can be updated to better designs without obsoleting or disturbing the billing meter. Auxiliary functions may be incorporated in future designs more easily, and more than one meter may share the same encoder hardware if the encoder register is external to the meter. An external encoder register allows isolation from surges such as lightning and power line transients which can cause erroneous readings and even burn out the encoder.

Whichever technique is used to obtain meter data from existing meters, meter accuracy requires that the technique be non-loading or, at least, cause very little load on the meter. When an encoder is attached to an existing meter, the additional mechanical load should not cause the meter to exceed its calibration tolerance.

Precision of Method 2 Encoded Meter Readings

Since the size and cost of the encoder is dependent upon the number of digits encoded, the "units" position of the meter reading is not encoded in some systems. After a meter is read, the AMR system multiplies the meter reading by 10 to get the actual usage.

Frequency of Interrogation

The size of the fixed usage quantity (Method 1 encoder) or the size of the usage register (Method 2 encoder) and the frequency of interrogation must be chosen so that (1) the cost of the encoder is minimal and (2) meter reading data is not lost due to recycling.

For Method 1, this means that the bi-stable switch in the encoder must not change its position twice before a meter reading is taken. In the Landis & Gyr system, the fixed quantity may lie between 3 and 20 KWH and the frequency of interrogation may be adjusted between 8 and 10 times in a 24 hour period.

For Method 2, the amount of usage between meter readings must not exceed the maximum number which can be represented by the encoder register. For example, assume the maximum representable quantity is N and the encoder register resets to zero when N is exceeded. If the previous meter reading was 0.5N, the usage during the current period may cause the meter to reset and start counting from zero. If the meter reading for the current period is less than 0.5N (0.15N, e.g.) the AMR system, by comparing the current reading to the last reading, can determine that the meter reset and calculate the usage by adding the current reading to the difference between the maximum register quantity and the last reading. (N - 0.5N + 0.15N = 0.65N). If the current reading exceeds 0.5N (0.6N e.g.), the AMR system will assume, in error, that difference between the current reading and the previous reading represents that actual usage (0.6N - 0.5N = 0.1N instead of 1.1N).

Preservation of Meter Readings During Power Failure

An important concern associated with AMR systems is what will become of meter readings when a power failure occurs.

With a Method 1 encoder, individual customer meter data is accumulated by the AMR system, not the meter/encoder. Assuming that the AMR meter data collection equipment has power failure protection equipment (auxiliary generator, battery, or computer system that stores all its important data as soon as a power loss is detected), a power loss at the customer site or at the utility central office will not cause data to be lost.

Method 2 encoders, which read the existing or auxiliary dials, also preserve meter readings when power is lost. The position of the dial will remain the same until power is restored. Aerospace Technology Corporation uses direct dial reading for its RMR system for this reason.

Depending upon the circuit design and the components used, Method 2 encoders which employ pulse counting digital registers may either lose the meter reading, keep the reading for a short period of time, or retain the reading indefinitely. Pranor Industries uses MOS integrated circuits in its encoder design because of the ability of these components to retain their states for a relatively long period of time after the supply voltage has been removed. While retention is not permanent, it may provide sufficient time to allow the power system fault to be found and corrected. Sangamo uses 120 VAC for normal operation of its PURDAX system, but contains rechargeable nickel, cadmium batteries to protect against voltage flicker and power outages.

Retaining Dial Readout on Existing Meters

If an AMR system collapses for one reason or another, the ability to revert back to the manual meter reading scheme may "save the day" while the AMR system is being repaired. Some manufacturers using modified existing meters retain the original visual readout dials or make provision for a dial face and pointers to be placed on extension shafts after the encoder is secured to the register mechanism.

CHAPTER FIVE
METER DATA SET/COUPLER

(3, 11, 12, 13, 14, 15, 16, 18, 22, 24, 26, 27, 31, 32, 33, 45, 46, 47, 50, 53, 56)

One meter data set/coupler is used for a small number of meter/encoders. In many cases there is a one-for-one relationship between the number of meter/encoders and the number of meter data set/couplers. Low initial cost, quick, easy installation, and maintenance-free, low cost operation are, therefore, desirable attributes of the meter data set/coupler component of automatic meter reading systems. The following techniques are used to implement the functions of the meter data set/coupler.

Transmission of Meter Readings

Meter data, compiled by the meter/encoder, may be transmitted over the meter data channel using one of several transmission modes. Described below are the most frequently used methods.

(a) Frequency Multiplexed Continuous Signals

By this method, a fixed number of parallel leads coming from the meter/encoder are read simultaneously by the meter data set/coupler and transmitted over the meter data channel as a simultaneous combination of audio frequency signals. The encoder generally used with this type of meter data set/coupler is a dial position reading, Method 2 encoder (see Chapter 4).

The parallel switch leads from the encoder are connected in series with capacitors or inductors in two or more audio oscillator circuits. The addition of incrementing capacitors changes the frequency of the oscillators. Each combination of continuous tones represents a unique meter reading.

An example of modulator circuit which produces a frequency multiplexed signal is the McGraw-Edison transponder shown in Figure 6. A.T.&T. Co. has a similar circuit in its experimental DATA-PHONE data set referred to as X406A.

Transmission of data as frequency multiplexed continuous tones is advantageous because of the simplicity of the meter data set.

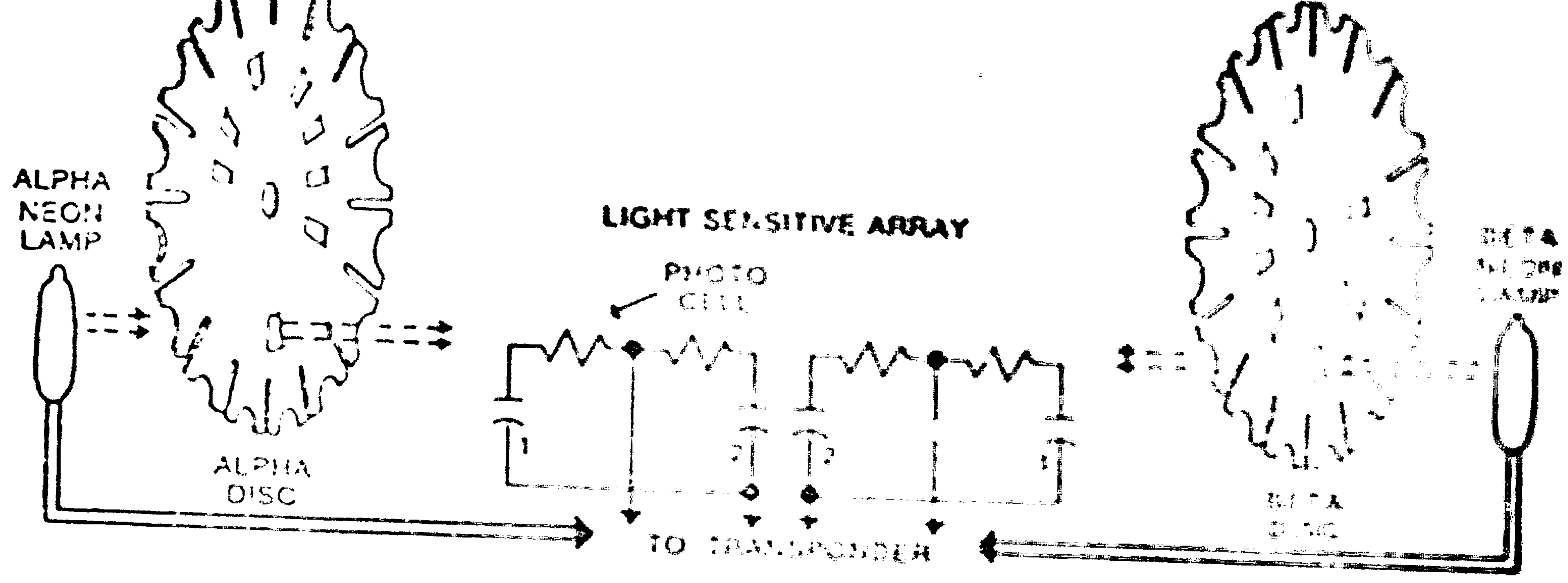
(b) Binary Strings using Frequency Shift Keying (FSK)

Data stored in pulse counting, Method 2 encoder registers (see Chapter 4) is generally transmitted over the data channel as a serial binary pattern. Binary ones are represented by a continuous signal of one frequency and a binary zero is represented by a signal of another frequency.

This kind of data set can be implemented by circular shifting the contents of the digital register located in the encoder past a keying circuit. The shift pulses can be obtained from a crystal oscillator or, where 110 V.A.C. is available, from the power system frequency. Sixty cycles per second is more than fast enough for transmitting meter data. The keying circuit inserts an additional capacitance in an oscillator circuit when a binary one is detected. Binary zero adds nothing to the oscillator circuit and thus the oscillator will transmit a "rest" signal.

The advantage of transmitting meter data as a serial bit pattern is the fact that only two frequencies are used for the signal.

ENCODER CIRCUITRY



DUAL OSCILLATOR CIRCUIT OF TRANSPONDER

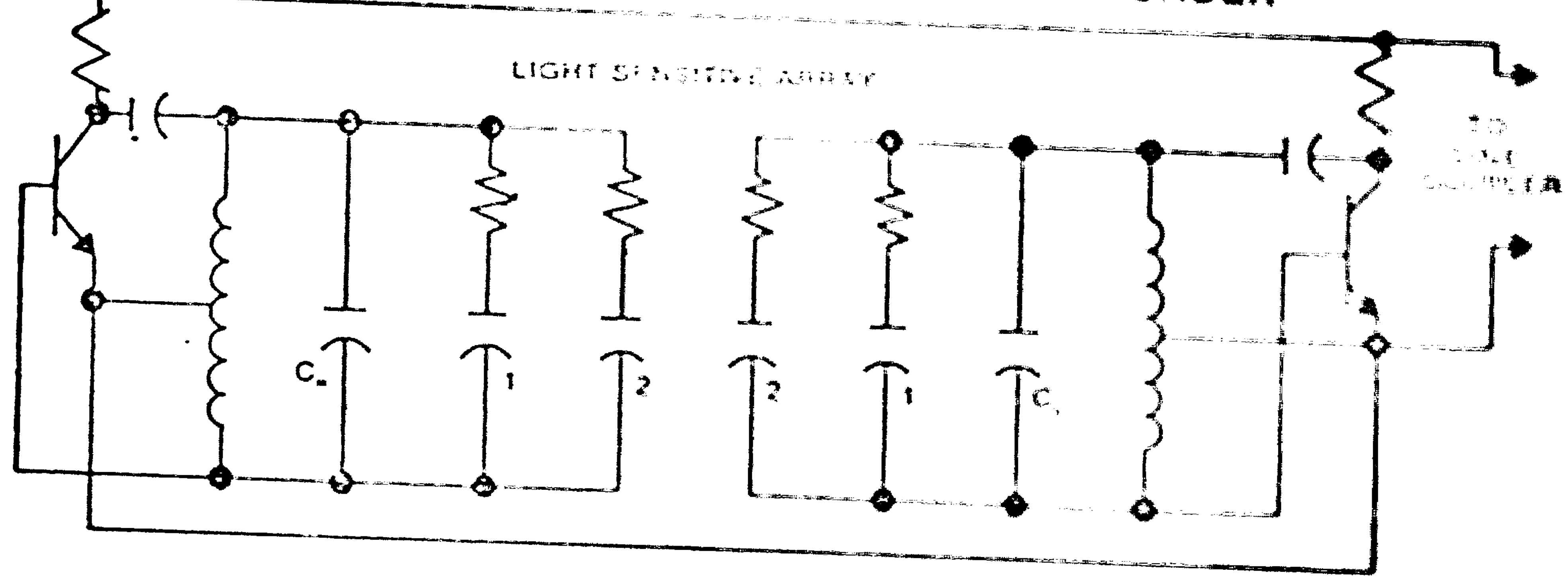


Figure 6

Modulator Circuit for Frequency Multiplexed **Continuous Signals**

(McGraw Edison, Inc.)

The choice of frequencies can be made so that the characteristics of the data channel can be optimized. FSK, as a result, can be used over practically any data channel.

Another advantage of transmitting readings in binary or binary coded decimal is the fact that this form of signal is more readily accepted by computers.

(c) Ripple Generation

Ripple generation is a technique used by automatic meter reading systems employing Method 1 encoders and power line data channels. Basically the transmitter is a simple L-C series circuit which is keyed by means of a series contact at half the power system frequency. As displayed in Figure 7, the generator is connected between a secondary phase wire and neutral. When activated, the predominant component of the current produced is a damped sine wave with a frequency equal to a harmonic of half the line frequency. The L-C circuit is tuned to the desired multiple of half the line frequency. The ripple signal current transmitted over the power line is used to represent one of the two states of the encoder bistable switch. A ripple generator is a feature of the Landis & Gyr Corp. automatic meter reading system.

(d) Impedance Representation

Usage may be "transmitted" as impedance of a circuit. In an early attempt at automatic meter reading, Zodiac Electronics Corp. developed a Method 2 encoder consisting of an electric watt-hour meter with a potentiometer connected to the hundreds dial. Using a telephone line as a data channel, meter readings were taken by first measuring the impedance of the telephone line without the potentiometer, then measuring

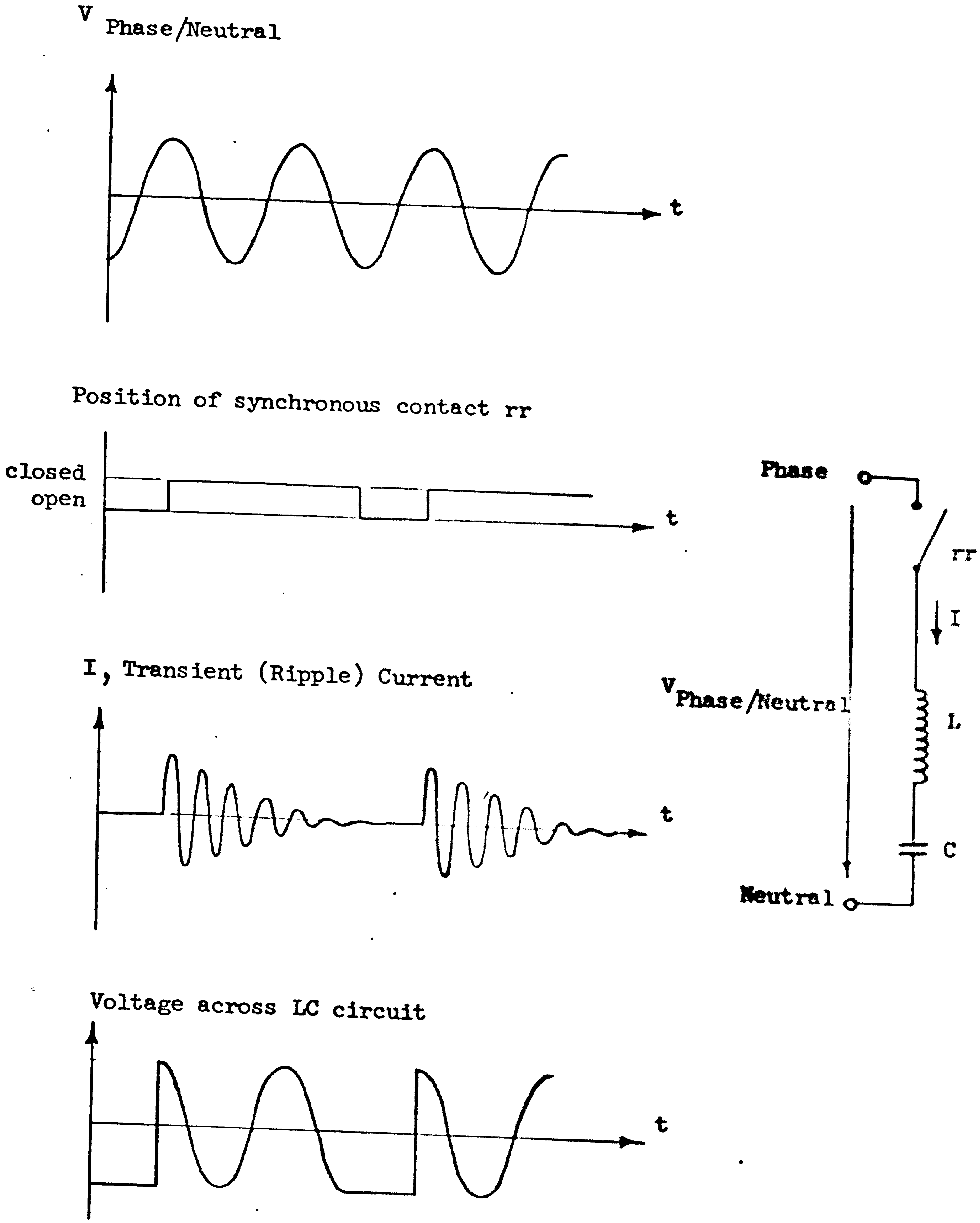


Figure 7

Ripple Current Generator Circuit
(Landis and Gyr, Inc.)

the impedance of the line with the potentiometer inserted. Usage was calculated by subtracting the former impedance from the latter and multiplying the difference by an appropriate conversion factor. Impedance was measured by a Wheatstone bridge arrangement at the utility office.

As far as Method 2 encoders go, this method of transmitting usage information was not very precise since a small error in impedance resulted in an error in the order of several hundred KWH. Also, line impedances may be affected by weather conditions.

The use of impedance in a Method 1 encoding scheme was demonstrated by General Electric in their experimental AMRAC system. Using "party line" pilot wires as the data channel, GE's transmitter consisted of a passive series resonant LC circuit with a shortable series resistor. The position of the encoder bistable switch determines if the series resistor is in line or shorted at any given moment. The switch changes position when one KWH is consumed. When a sinusoidal signal having the same frequency as the resonant circuit is applied to the party line a small or large current will flow depending upon the Q of the circuit. The large current represents one position of the switch and the small current the other. Since the L-C circuits at other meters on the party line are tuned to different frequencies, the current contribution from other meters will be negligible. A sweep generator can then scan all the meters on the party line periodically and the AMR system can accumulate meter reading data.

Addressing Meters

The meter data channel selected for the automatic meter reading systems will determine, to a certain extent, the way in which each customer meter installation will be addressed.

(a) Telephone Line Addressing

When the telephone network is used as the data channel, customer telephone numbers serve as meter identification numbers. The AMR system must have provision to "dial" each customer meter, select the appropriate telephone line to the customer, couple the customer meter data set to the telephone line, and retrieve the meter reading.

(b) Digital Discrete Addressing

Power line, pilot wire and some radio data channels require quite a different treatment. All customer data sets are essentially connected to a large "party line". Control signals sent over these data channels are heard by all meters on the AMR system. In order to obtain meter readings from individual meters, a digital address for each meter is stored in the AMR system and sent sequentially over the party line. Each meter has its own discrete address. While all data sets will receive the interrogation, one and only one data set will respond by sending back a meter reading. This is illustrated in Figure 8. Digital discrete addressing allows the utility to interrogate all its meters from one interrogation station.

The digital discrete addresses are usually sent by the AMR system in binary form using FSK. This permits the interrogation of a large number of meters with a minimum amount of address hardware in the

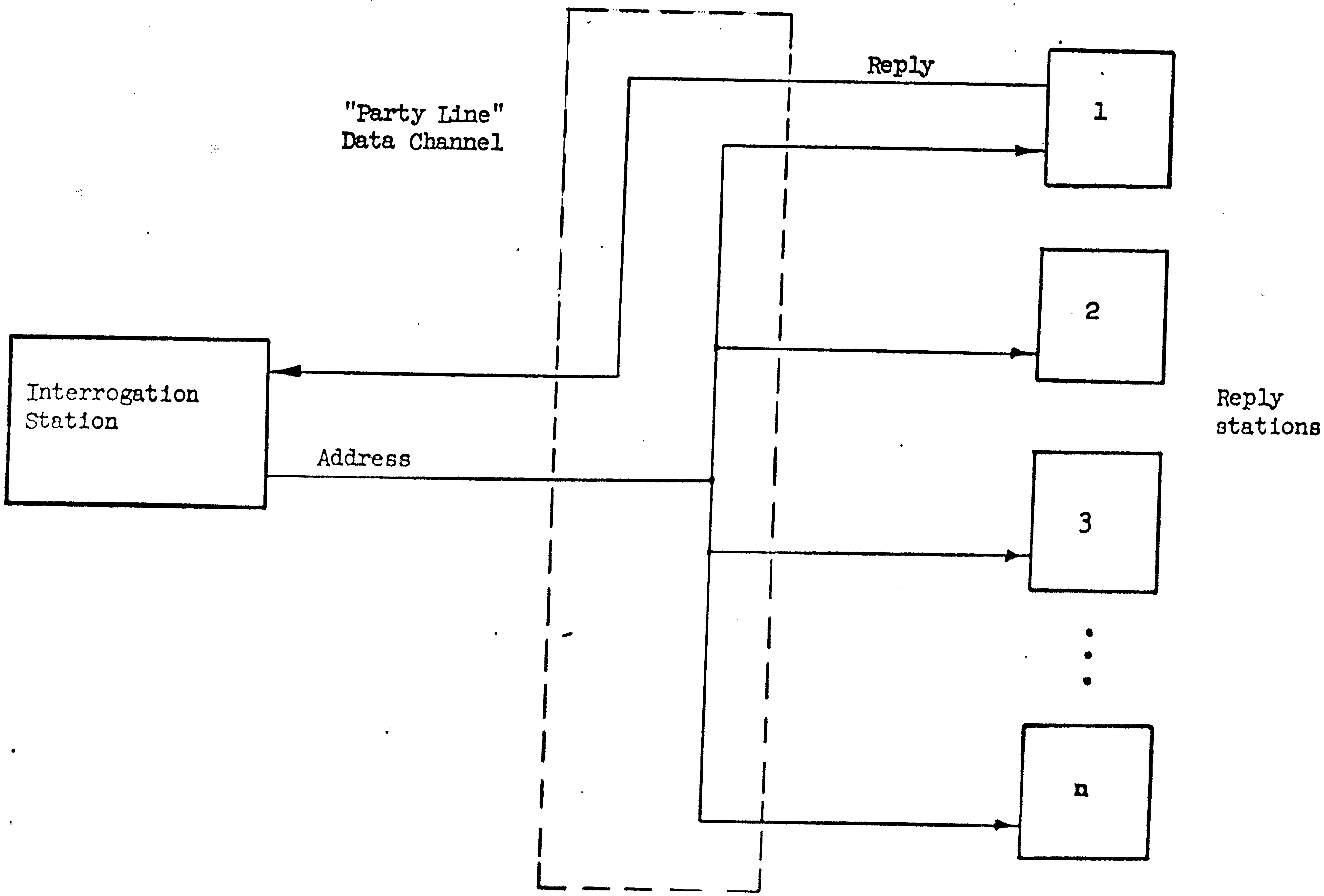


Figure 8

Digital Discrete Addressing
(North American Research, Corp.)

customer meter data set. A twenty bit address, for example, would handle a million customers. The address hardware located in the meter data set consists of compare circuitry. If the binary number received over the data channel agrees with the address of the meter, a gate will be opened causing the meter reading data to be transmitted.

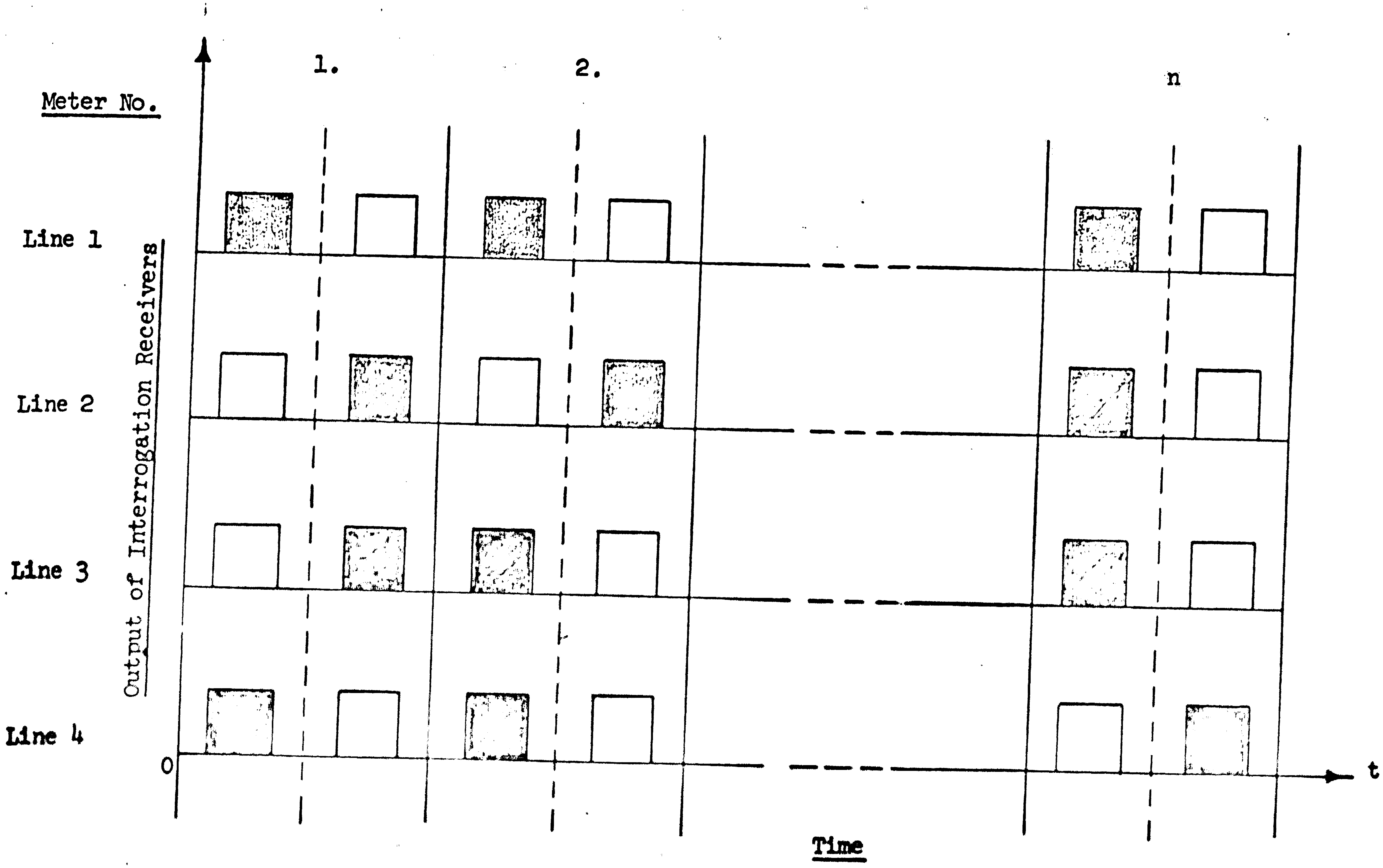
The disadvantage of this method of addressing is the cost of the additional addressing circuitry needed in the meter data set. Also, data sets with addressing circuitry are not readily interchangeable.

(c) Spacing Replies in Time

At times the "address" of the customer meter consists solely of knowing when, in time, with respect to some reference point, to expect a meter reading signal to come in from a remote customer meter. Such an approach was employed by Landis and Gyr, Inc.

In the Landis and Gyr automatic remote meter reading system, the transmitters of all meters connected to the secondary of a three phase, underground network, distribution transformer are started at the same time by a ripple control signal. The responses from the meters, however, are transmitted at different times with respect to the start time. As depicted in Figure 9, only 400 meters may be connected to one party line, but more than one line may be interrogated simultaneously by similar interrogation equipment.

Note that the two bistable states in this Method 1 system, are represented by signals which are, likewise, spaced in time. If the bistable switch is in one position a signal will occur at one point in time. If the switch is in the other position a signal will occur at another point in time. Both time slots, however, are allocated to a specific customer.



All meters activated at t = 0

Figure 9

Spacing Replies in Time

(Landis and Gyr, Inc.)

(d) Discrete Frequency Addressing

Another approach to addressing meters on a party line data channel is to transmit control signals of different frequencies. Each meter data set can then have a receiver that is tuned to a small unique range of frequencies. When the signal of the correct frequency is received, the meter data set will transmit the meter reading.

Although this method sounds plausible, closer examination points out several weaknesses. First of all the data channel would have to pass a large range of frequencies with near equal attenuation. Few party line data channels possess such characteristics.

Secondly, each receiver has to be tuned to a different frequency. In larger utilities this means more than a million different tuned circuits, one for each customer.

With these handicaps to contend with, the use of discrete frequency addressing is best used with a limited number of meters on a pilot wire data channel. Such an installation was used by General Electric in their Method 1 AMRAC system.

Customer Identity Verification

After a customer meter data set is addressed, the meter data transmitted over the data channel may be identified by the meter data set in order to provide customer identity verification. Some manufacturers skip this feature and assume that the reading coming back over the data channel after an addressing operation is coming from the intended meter installation. Manufacturers who provide identity verification usually use one of the following methods.

(a) Rest Tone Reference Signal

Data sets which transmit meter readings as frequency multiplexed continuous signals can provide identity verification by allowing the tone generator to transmit a continuous rest signal before the incrementing capacitors representing the meter reading are inserted into the oscillator circuit.

(b) Identification Bits

Data transmitted as binary strings can be identified by appending identity verification bits to the bit string representing the meter reading. The meter address is often used for the verification bits when digit discrete addressing is employed. If FSK is used for addressing and meter data transmission, and if the two frequencies used for addressing are different from the two frequencies used for data transmission, identification bits will allow addressing and data transmission to occur simultaneously. This reduces the over-all time to interrogate customer meters.

Energy Source for Meter Data Set.

The source of power for the meter data set may either be a local source, the meter data channel, or a combination of the two.

The obvious advantage of obtaining power from the data channel is the savings in power supply components at the meter installation. Secondly, supplying power over the data channel solves the problem of what to do when there is no local power source. This situation may occur for isolated water and gas customers. Besides merely supplying power, power from the data channel can serve as an alerting signal which turns on normally dormant meter data set circuitry. Of course, the encoder must be a dial position reading type which requires no power until a reading is transmitted.

Alerting and Coupling the Meter Data Set to the Telephone Network

When the telephone network is used as a data channel, additional circuitry is required in the meter data set to couple the data set to the line for a meter reading. A complication arises in that the alerting signal which activates the coupler must not cause the subscriber's telephone to ring. The following methods are used by manufacturers to alert and couple telephone lines to meter data sets.

(a) D. C. Alerting

In this method, a direct current alerting signal is applied to a selected customer line by a special arrangement in the telephone company switching exchange. The customer's telephone is prevented from ringing by increasing the voltage gradually to a voltage which is below the ordinary bell ringing voltage. When the reading is completed, the voltage is reduced gradually to zero. An example of this type of d.c. coupler is the McGraw-Edison coupler shown in Figure 10. In the normal state, the photocell provides a high impedance path between the meter data set and the telephone system. When a d.c. alerting signal is applied, the neon lamp in the line coupler turns on. This, in turn, reduces the impedance of the photocell and couples the line to the data set. A time delay circuit prevents activation by stray pulses.

(b) Tone Alerting

With this method, a tone, originating at the telephone exchange, is received by a tone receiver in the coupler. The receiver causes the line to be coupled to the meter installation. The advantage of using

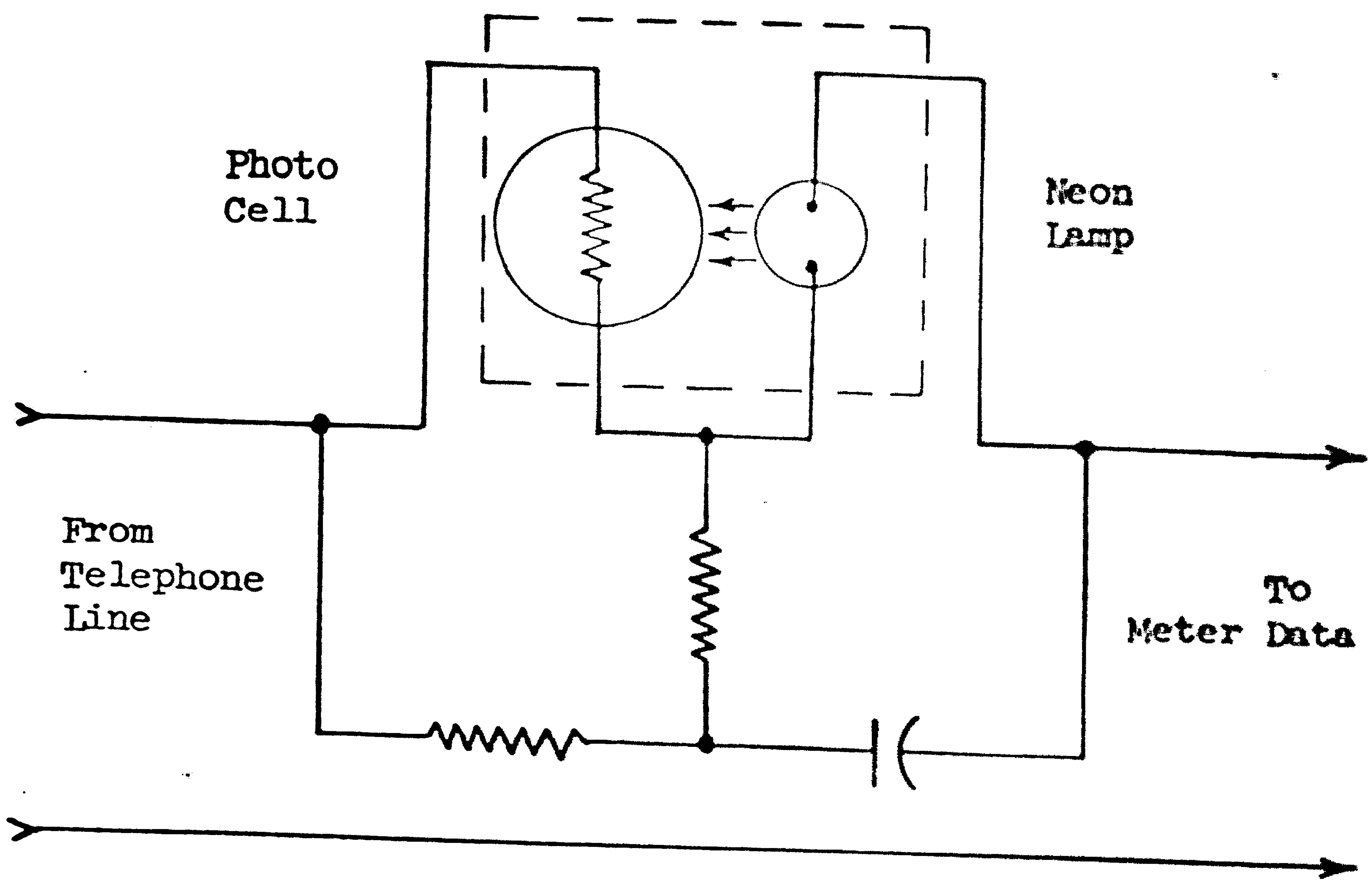


Figure 10

D.C. Coupler for Telephone Lines
(McGraw Edison, Inc.)

tone rather than d.c. coupling is that tone alerting is more compatible with future telephone system developments. The telephone system of the future will not tolerate high voltage d.c. signaling.

A.T.&T. presently has a coupler which uses tone alerting and also supplies a limited amount of d.c. power to operate the data set for a two second interval.

Multiple Metering Over Telephone Lines

Many customers are simultaneous gas, water, and electricity users. Other customers share a party line telephone arrangement. In both cases, more than one meter could be read with one addressing operation if the telephone network is used as a data channel.

When meter readings are transmitted as frequency multiplexed continuous signals, more than one data set may be connected to the same data line by dividing the available band of frequencies into channels, one for each modulator. Preassigned rest tone signals would then identify each meter-user and serve as a frequency reference. Meter readings would then be represented as changes in frequency from the reference frequency. McGraw Edison's ARMETER system uses this technique for simultaneously reading up to six meters with one telephone call. The six meters represent three meters at two separate homes which share a common telephone line.

Alternately, when meter readings are transmitted as binary data using FSK, several meter readings plus verification bits may be serially scanned at one time by the data set. Scanning circuitry can be shared by more than one meter in this case.

Multiple meter reading of gas, water, and electric meters assumes that one automatic meter reading system will be used by one organization to compile meter data for all utilities. If this is not agreeable to all parties involved, multiple metering can only be used to read the meters of the same utility on party lines.

CHAPTER SIX
METER READING DATA CHANNELS

(1, 2, 3, 4, 5, 8, 11, 12, 13, 14, 15, 16, 18, 22, 26, 27, 30, 32, 33, 37, 40, 41, 42, 46, 47, 48, 53)

There are basically four types of data paths or channels which can be used for automatic remote meter reading systems. They are:

(a) Electric power lines,

(b) Telephone lines,

(c) Pilot wires, and

(d) Radio

Electric power line data channels make use of the electric distribution system to transmit meter reading data and control signals. The switched telephone network is used for telephone line data channels. Pilot wires are data communications paths which are built specifically for automatic meter reading. Radio communications utilize a portion of the radio frequency spectrum to convey meter reading data.

Once selected, the data channel will impose many constraints on the selection of other system components. Therefore, the nature of the available data channels and the advantages and disadvantages of using one data channel over another should be closely examined.

Universality of Data Channels

An important consideration in choosing a data channel is the extent to which a data channel can be used to read utility meters. It should be possible to read all or practically all the utility meters over the chosen data path. For the electric utility, the electric distribution network is a logical choice since each electric utility customer is connected to the data channel.

Although telephones are a common luxury these days, not all utility customers have a telephone. If telephone lines are selected as the data channel, a special line would have to be installed to a utility customer who does not wish to subscribe to telephone service.

Pilot wire data channels, by definition, are installed specifically for automatic meter reading and, thus, must be universal to all utility customers.

Radio provides a universal data channel if antennas at customer meters can all be located "in the clear". Obstructions such as tall buildings with metallic framework, underground installations, and strong electromagnetic fields caused by power generating stations and radio and television transmitters may require an alternate data path for some customers.

Coordination of Additions and Removals

Depending on the type of utility (gas, water, electric) and the data path chosen, each meter data set installation or removal may require the joint effort of the utility and another company. It is, of course, desirable for a utility to avoid involvement with a second party because of coordination problems that arise.

The advantage enjoyed by an electric utility using power line data channels is complete control over the meter reading data channel. Meter data sets can be installed and removed where and when required by the power utility.

An electric utility which elects to use telephone lines as a data channel must coordinate each meter installation with the telephone company. A new installation may require telephone personnel to connect the customer meter data set or coupler to the telephone network. Since each utility customer is identified by a telephone number, the telephone company would have to continually supply updated telephone number information to the utility for its AMR master file. It is estimated by some utilities that 150,000 address changes occur in a year. This translates to 200 to 300 telephone number changes per day.

The chart in Figure 11 shows the maximum number of companies, including the installing company, that may be involved in putting in a customer meter installation on one of the available data channels.

Dedication of Data Channels

A dedicated meter reading data channel is defined here as a data channel which is used solely for remote meter reading and related auxiliary functions. According to this definition electric power lines and pilot wires are dedicated channels, radio is a semi-dedicated channel, and telephone lines are shared lines.

Because of the greater probability of more phones being busy during work hours and evenings, the use of telephone lines for meter readings is best confined to the period from midnight to 7:00 A.M. Therefore, telephone lines not only restrict the frequency of use of the AMR system, but also restrict the time period during which the system may be efficiently used. Dedicated channels, including radio, do not impose this restriction.

Another consequence of using non-dedicated telephone lines is the necessity to coordinate the design of AMR hardware with telephone company equipment. The telephone company is justifiably concerned

Meter Reading Data Channel	Electric	Gas	Water
Electric Power Lines	1	2	2
Telephone Lines	2	2	2
Pilot Wires	1	1	1
Radio	1	1	1

Type of Utility

Figure 11

Maximum Number of Companies Involved in Installing Customer AMR Equipment that AMR additions to the telephone system could compromise the subscriber's basic telephone service or that such additions would not be compatible with planned and unplanned advances in the telephone art. To insure the integrity of the telephone system, American Telephone and Telegraph Company has developed experimental hardware to interface with utility meter installations at the customer end and with the utility data compiler at the utility central office. Two different arrangements are provided at the customer meter. The utility may use a modified DATA-PHONE data set (coded X406A) for coupling to the telephone lines and transmitting meter data or the utility may use its own meter data set attached to a Remote Meter Access Arrangement (RMAA) supplied by A.T.&T. The RMAA is essentially a line coupler similar to the devices described in Chapter 5. The telephone central office is equipped with a Meter Reading Access Circuit (MRAC) which connects the utility data processing equipment to MRAC, connects the utility to the proper customer phone lines, supplies alerting signals which will not ring the customer's telephone, and passes meter data from the customer meter data set to the utility. At the utility, a Data Communications Terminal (DCT) X406B interfaces the utility data processor with the MRAC.

Bypassing Distribution Transformers

A problem facing prospective power line data channel users is the presence of transformers on the distribution lines. Distribution transformers present a very high impedance path to data frequency signals which causes the signal-to-noise ratio to deteriorate severely. This problem is critical in transmitting meter data to the interrogation center since it is desirable to limit the power output of the meter data set to a few milliwatts for economic reasons. Passive, capacitive bypasses around transformers are not acceptable because transients and surges are propagated.

One solution, offered by North American Research Corporation, is to use wireless bypasses consisting of low power radio, optical (open or fiber optics), or acoustic transceivers spaced a few inches apart. This arrangement is displayed in Figure 12. The transceivers would transmit addressing signals to the customer meter installation and transmit meter data to the interrogation station. Since a bypass would be required at many power system distribution transformer locations, this solution would be very costly indeed.

Another solution is to have more than one interrogation station. The interrogation stations could then be placed relatively close to the customer meter installations so that the effects of the high impedance can be tolerated. The separate interrogation stations can be operated in parallel.

A third solution, which can be used in underground networks, is to decouple the meter reading signal on the secondary side of the network transformers and thus avoid the problem entirely.

Cost of Pilot Wire Data Channels

Although pilot wire data channels can be "tailor made" for automatic meter reading, the cost of building a new communications network whether on poles or buried, most probably cannot be justified for automatic meter reading alone. The liberal application of auxiliary functions is required to defray the initial cost of a pilot wire data channel.

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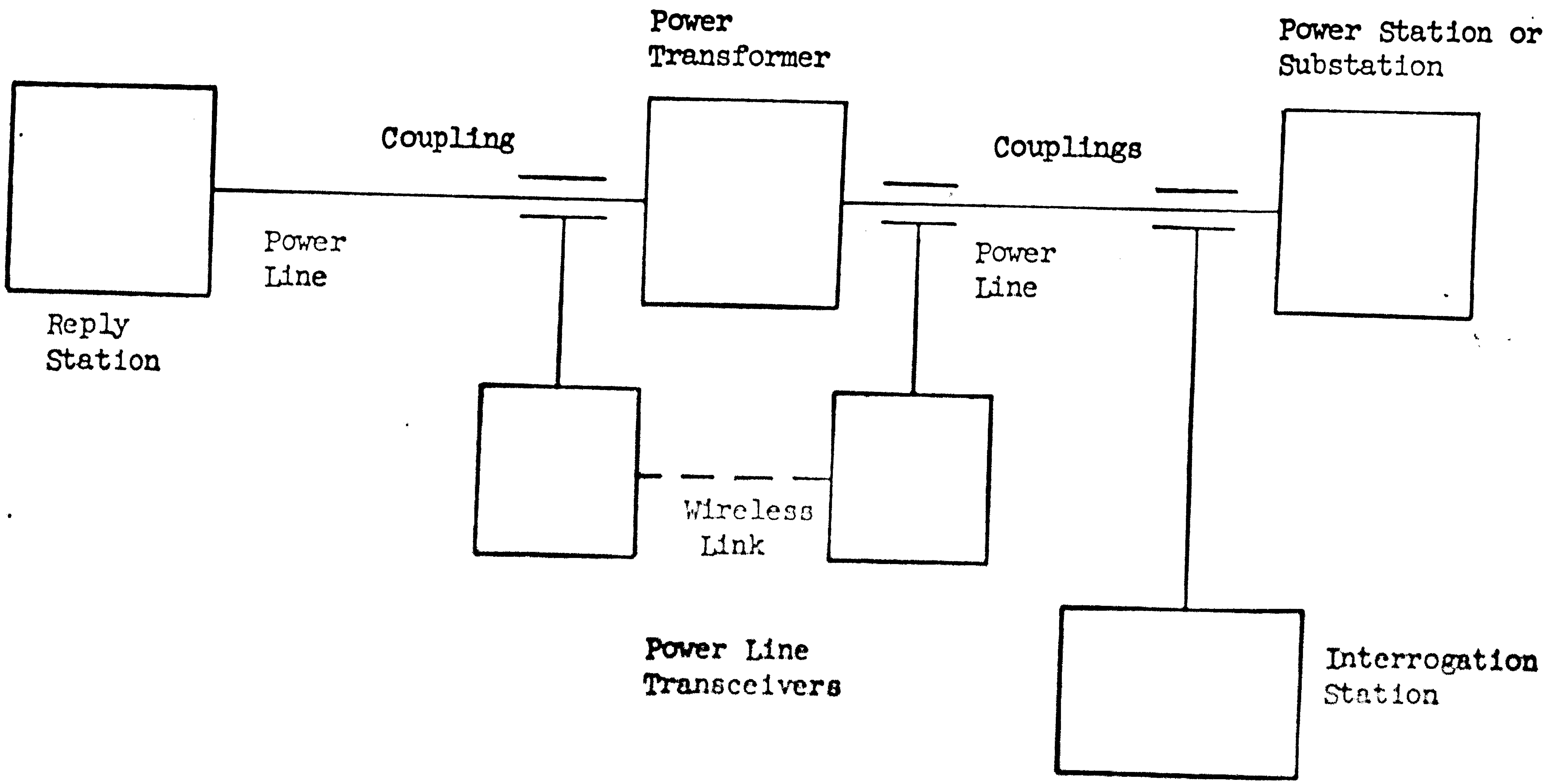

Figure 12

<u>Bypassing Transformers on Distribution Systems</u>
(North American Research Corp.)

Radio Spectrum Used for Telemetry

A Federal Communications Commission license is required to use a radio telemetry channel for automatic meter reading. To obtain a license for this new application, a petition must be filed before the F.C.C. The selection of an operating band is not left up to the sole discretion of the meter reading system component manufacturer. Rather, the manufacturer must seek to use one of the spectrum bands allocated by the F.C.C. for telemetry. The available frequencies may require costly transmitter and receiver designs, and the performance of a meter reading system in the available bands may be far from optimum.

CHAPTER SEVEN
INTERFACE/DECODER

The interface/decoder is a sophisticated device which, in conjunction with the meter reading data compiler, controls the operating cycle of the automatic meter reading system. Unlike the meter/encoder or the meter data set/coupler which are located at each customer meter location and require rigid economy-oriented design, the interface decoder is generally located at the utility central office or in an interrogation van or craft and is designed to perform as much of the system work as possible. The cost of this component, no matter how great, will be small in comparison to the total cost of customer meter installations.

In general, the functions of the interface/decoder are:

(a) Coupling the meter reading data compiler to the meter reading data channel,

(b) Addressing and alerting customer meter installations,

(c) Receiving and decoding meter reading data,

(d) Detecting abnormal system conditions, and

(e) Controlling the meter reading cycle between the time a customer address is presented to the interface/decoder and the time the interface/decoder presents the meter reading to the data compiler.

CHAPTER EIGHT
METER READING DATA COMPILER

(2, 12, 13, 15, 16, 24, 26, 27, 29, 32, 33, 46, 50, 54)

The data compiler portion of the automatic meter reading system controls the overall operation of the system and compiles meter reading data in a form that can be used in the billing process. The cost of the data compiler, like the cost of the interface/decoder, will be small in comparison to the total cost of meter/encoders and meter data set/couplers.

Types of Meter Reading Data Compilers

Three basic configurations are used for the meter reading data compiler. They are:

(1) Modified Adding Machine, Teletype Terminal, or Nixie Tube Display - With this arrangement an operator manually controls the meter reading cycle by typing in customer identification numbers and receiving, in return, a typed out meter reading on a modified adding machine or teletype printer, or a visual display on a Nixie tube array. Errors and fault conditions are indicated or typed out on the same output device for the attention of the operator. This arrangement is best suited for small utilities where the billing process is not highly automated.

(2) Mini-computer - A small, low cost mini-computer connected to the interface/decoder controls the overall operation of the AMR system and compiles the meter reading data. A device such as a magnetic tape drive or a paper tape reader is required to input identification codes of customers to be interrogated and a magnetic

tape drive or a paper tape punch is required to output meter readings or error codes and associated identification codes. A teletype terminal such as an ASR33 or ASR35, a card reader, and a high speed paper tape punch are desirable to maintain the system hardware and to perform manual operations. Figure 13 displays this configuration.

(3) Time Shared Billing Computer - The interface/decoder is connected directly to a large, commercial time sharing computer in this configuration. The time sharing computer treats the interface/decoder as a slow input/output device. All processing of data and error or fault conditions is handled by the large processor in a multiprogramming environment.

Functions of the Meter Reading Data Compiler

In addition to controlling the automatic meter reading cycle and compiling meter reading data, the data compiler component performs the following tasks.

(a) Checks meter reading data for errors.

(b) Identifies system problems requiring maintenance.

(c) Transfers meter reading data from the data compiler to the billing process.

(d) Provides means to interrogate manually from a keyboard for start and closeout readings and for testing repaired meter installations.

(e) Performs auxiliary functions if incorporated in the automatic meter reading system.

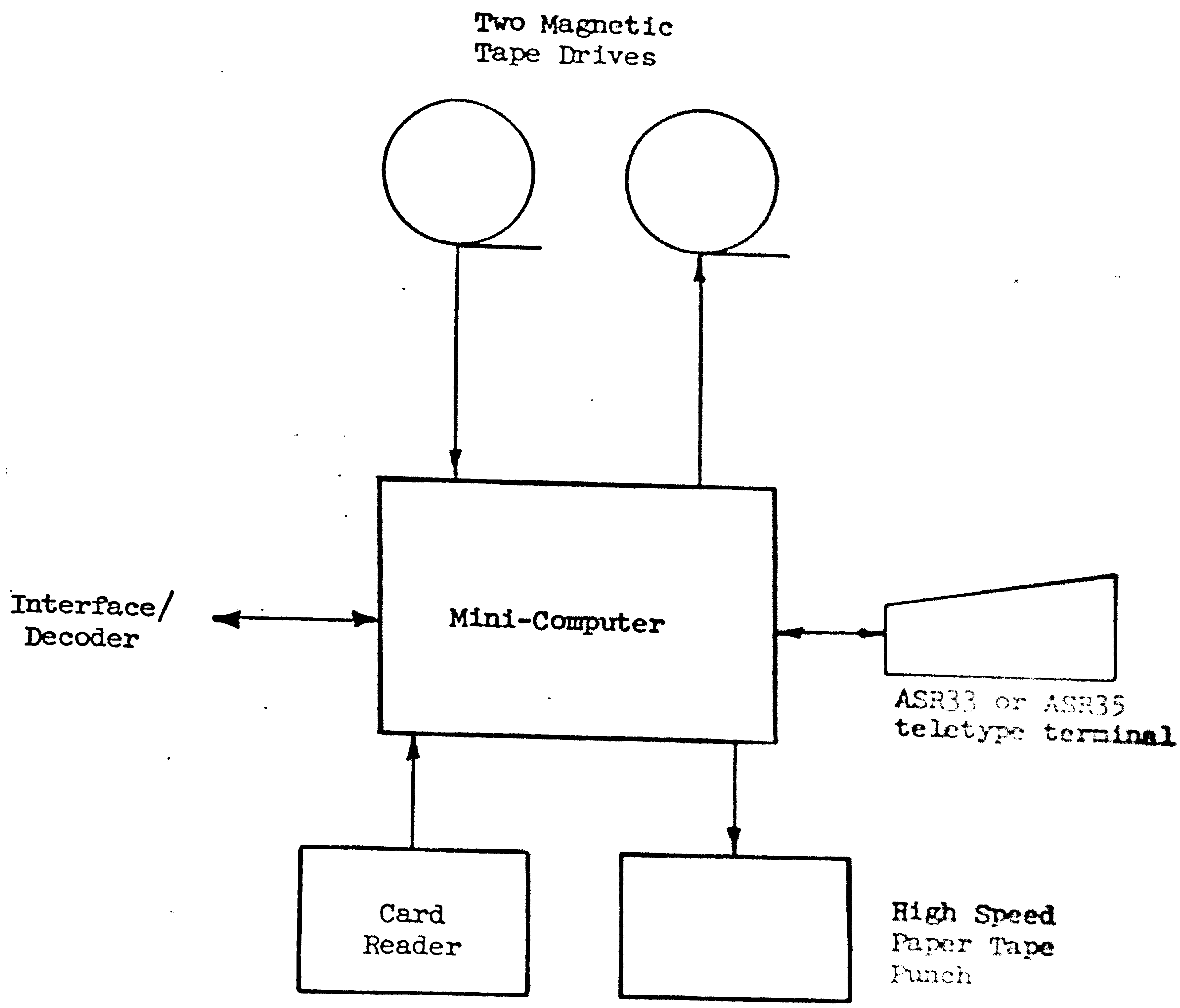

Figure 13

Mini-computer Configuration

CHAPTER NINE
AN OPTIMUM AUTOMATIC METER READING SYSTEM

(18, 19, 48, 50)

As indicated in the previous chapters, many technical alternatives exist for each component of the generic automatic meter reading system. The combination of components which yields the least initial expenditure and least additional operating costs while offering the greatest operating advantages necessarily is the optimum choice of components.

Author's Choice of AMR Components

Of the available data channels, telephone lines appear to offer the greatest economic advantage. The fact that the telephone network is, in effect, a large message switching computer alleviates the AMR system of most of the meter addressing function. Customer meter data sets can be made simpler, and, hence, more economically because of the lack of addressing circuitry.

Telephone lines are existing data paths designed to enhance communications. For most utilities, only one interrogation site is required to read all utility meters. The fact that telephone lines are not connected to every gas, water, or electric customer residence is a coordination problem --- not a technical problem. Telephone companies and other utilities can engage in agreements whereby the telephone company will install telephone lines where needed for automatic meter reading. There is precedence in joint use agreements between telephone companies and power companies for the installation of shared poles.

Similar cooperation can be arranged for the installation and removal of meter installations and the updating of telephone numbers.

Although manual meter reading expenses per meter per year vary quite a bit from utility to utility, a 1963 University of Michigan study of a system having 1,350,000 meters indicated that the cost of taking meter readings was $1.33 per meter per year, the cost to collect and process meter readings (i.e., put in computer compatible form for eventual billing) was $4.29 per meter per year, and delays in billing cost $0.44 per meter per year. This results in a total collection cost of $6.06 per meter per year or approximately $0.50 per meter per month. Under present tariffs, American Telephone and Telegraph Company charges $2.00 per month for each data coupler attached to their system. Even with today's high inflation rate, it would take a very long time to justify the use of telephone lines with this steep monthly charge.

The American Telephone and Telegraph Company, however, has recently developed experimental equipment which interfaces with the utility decoder and data compiler at the utility interrogation center and with the utility meter data set or meter/encoder at each customer site. (See Chapter 6 for a more detailed description). Additionally, AT&T has conducted several successful trial programs (Phases I, II, IIA, and III) in conjunction with AMR equipment manufacturers. These trial programs gave manufacturers an opportunity to develop their equipment and gain some practical experience with a telephone line oriented AMR system. AT&T also refined their equipment during the trials.

It seems apparent to many, including the author, that AT&T will eventually file with the F.C.C. and state regulatory bodies for a new, lower cost tariff for automatic meter reading. AMR offers a new source of revenue for the telephone companies by making use of telephone facilities in an off-peak period of the day. With telephone company couplers or approved couplers supplied by AMR equipment manufacturers, there is little or no risk to telephone system integrity. A call which takes two seconds instead of three minutes should result in a lower monthly charge. (A figure of $0.50/meter/year was suggested by AT&T as a "horseback" estimate to McGraw-Edison in 1968). Cooperation between a gas, water, or electric utility and a telephone company is much different than allowing an unregulated outside manufacturing firm to attach to the telephone system.

The choice of telephone line as the data channel dictates the use of Method 2 encoding. Modified, conventional gas, water and kilowatt-hour meters are the most economical choice at this time. Advances and standardization in solid state metering may eliminate conventional meters in the future. Dial position reading, Method 2 encoders are simpler than pulse counting encoders and, hence, less expensive. Another advantage of dial position reading encoders is the fact that these devices are passive most of the time, being activated only during a meter reading. Power failures are, thus, no problem with this type of encoder.

Utilities should be able to use the dial position reading encoder on meters produced by all the major gas, water and kilowatt-hour meter manufacturers. An auxiliary dial mechanism, which is quickly attachable to the original meter register, is more likely to meet this requirement than an encoder which reads the position of the original dials. The original dials should be retained, however, for occasional manual reading.

The capacity of the encoder should allow the utility to interrogate most customer meters once a month, for billing. The AMR system should not have to call more frequently in order to prevent the encoder from recycling.

The simplest method of transmitting meter data encoded by a dial position reading encoder is to employ a frequency multiplexed continuous tone modulator in the meter data set. The meter data set should be supplied by the AMR equipment manufacturer --- not rented from the telephone company. A rest tone reference signal, which is easily implemented with a tone modulator, will serve adequately to verify customer identities.

Multiple metering can best be accomplished by using tone alerting. Not only will tone alerting be compatible with future telephone company plant, but tone alerting will allow meter data sets connected to the same telephone line to be selectively activated. The probability is high that gas, water, and electric utilities operating in approximately the same area, will want to collect their own meter data. Each utility, using a different tone(s) for alerting, can interrogate its meters alone. Of course, multiple meters on a party telephone line, belonging to the same utility can be interrogated selectively or simultaneously with tone alerting.

Power to operate the meter data set should be obtained from the data channel in order to avoid the added expense of a local power supply.

Since the American Telephone and Telegraph Company serves about 80% of the subscribers in the United States, AMR equipment should be designed to function with the AT&T Data Communications Terminal (DCT), Meter Reading Access Circuit (MRAC), and Remote Meter Access Arrangement (MRAA) or similar equipment. A separate decoder is required with the DCT to receive and decode frequency multiplexed continuous signals.

A mini-computer provides the most versatile meter reading data compiler. A configuration consisting of a low cost mini-computer, an ASR33 or ASR35 teletype terminal, a card reader, a high speed paper tape punch, and two magnetic tape drives (see Figure 13) is desirable.

Outlook for Automatic Meter Reading

As described in Chapter 2, each utility, contemplating the use of an automatic meter reading system, must make a feasibility study on its particular organization in order to tell when an AMR system is feasible. Utilities with highly urbanized and highly rural territories will be the first to need AMR. Although many successful experimental AMR systems have been built, AMR systems which use telephone line data and components which are similar to the components described above, will, most probably, be accepted and used by utilities in the near future.

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APPENDIX

Experimental Automatic Meter Reading Systems

Manufacturer	Aerospace Technology Corporation, Hackensack, New Jersey
System Name	Remote Meter Reading System
Acronym	RMR
Meter/ Encoder	Conventional watthour, gas, or water meters modified with optical, dial position reading, Method 2, internal encoder. Five decades encoded in BCD form. Dial faces and pointers may be replaced on top of encoder package, if desired, for visual readout. Optional solid state watthour meters available.
Data Set/ Coupler	Data set transmits BCD encoded data as a binary string using FSK. Twenty-four bit address is appended to meter reading for customer identity verification. Digital discrete addressing is employed.
Data Channel	Electric power distribution system.
Interface/ Decoder	Digital discrete addressing transmitter and FSK binary receiver.
Data Compiler	Details not available.

Manufacturer	General Electric Co., Somersworth, N.H.
System Name	Automatic Meter Reading System
Acronym	AMR
Meter/ Encoder	Conventional watthour, gas, or water meters modified with dial position reading, Method 2, internal, magnetically driven reed switch encoder. Encodes up to 1[illegible] kWh before recycling. Requires 2 readings per month for most electric customers. Original dials retained.
Data Set/ Coupler	A.T.&T. Co. Residential Utility Meter Reading Data Set, X406A (M12). The data set, used in the parallel mode, transmits meter data as three frequency multiplexed continuous tones.
Data Channel	Telephone lines. Telephone central office is equipped with A.T.&T. Co. Meter Reading Access Circuit (MRAC).
Interface/ Decoder	A.T.&T. Co. X406C1 Data Communications Terminal (DCT) and G.E. frequency multiplexed tone decoder.
Data Compiler	ASR 35 teletype terminal.

Experimental Automatic Meter Reading Systems

Manufacturer	General Electric Co., Somersworth, N.H.
System Name	Automatic Meter Reading and Control System
Acronym	AMRAC
Meter/ Encoder	Conventional watthour meters modified with internal, bi-stable, passive switch for Method 1 encoding. Switch changes state each time one KWH is consumed. Encoder scanned every 75 seconds.
Data Set/ Coupler	Data set consists of a resonant circuit having two values of impedance at its resonant frequency. The bi-stable switch in the encoder switches a resistor in the circuit and thus changes the Q of the circuit. Each meter "data set" on a line is tuned to a different frequency between 4 and 50 kc.
Data Channel	Pilot wires. One hundred (100) meters attached to one, 2 conductor pilot wire party line; ten party lines per addressing section; sixty (60) sections employed (60,000 total customers).
Interface/ Decoder	Section equipment, consisting of solid-state devices in a box mountable on a pole, performs stepping-switch function and provides sweep frequency signal and means of measuring current as function of frequency. Status of each section (there are 60) is sent to reading center over a pair of wires.
Data Compiler	Position of bi-stable switch in 60,000 meters is recorded alternately, every 75 seconds on one of two magnetic drums. Data from drums checked and accumulated on magnetic loop tape recorder. Data taken from loop recorder at end of billing period.

Manufacturer	Hunter Electronics, Inc., Hialeah, Florida
System Name	Hunter Remote Meter Reader
Acronym	----
Meter/ Encoder	Conventional watthour, gas, or water meters modified with micro-switch, light emitting diode, or magnet and reed switch connected to units position. Dial face retained. External, BCD, pulse counting, Method 2 encoder employed. Four decimal digits encoded. Battery back-up used for power supply.
Data Set/ Coupler	Data set reads back each digit under control of reset pulser. Each counter resets to zero as data set sends out reset tone bursts on telephone lines to central office. Unique coupler "seizes" line [illegible] milliseconds after line is selected by central telephone office. Subscriber cannot use phone until meter reading is complete.
Data Channel	Telephone Lines. Unmodified telephone company central switching office.
Interface/ Decoder	Hunter Central Office Read-out Unit.
Data Compiler	Manual or computer control.

Experimental Automatic Meter Reading Systems

Manufacturer	Industrial Process Engineers, Newark, New Jersey
System Name	I.P.E. Home Meter Reader System (Method "A")
Acronym	----
Meter/ Encoder	Conventional watthour, gas, or water meters modified to encode four decimal digits in digital form. Method 2 encoding employed.
Data Set/ Coupler	Upon request, a transmitter sends out a serial binary pattern representing a meter reading. A binary customer identity verification code is also sent.
Data Channel	Telephone lines. Telephone company fault scanner is used for selectively and inaudibly "ringing" customer meters.
Interface/ Decoder	I.P.E. Central Office Data Logger, located at telephone exchange, receives digital meter data from fault scanner, checks for low level errors, stores meter readings on tape, and transmits data, upon request, to I.P.E. Equipment at utility computer center via high speed telephone data lines.
Data Compiler	I.P.E. Primary Data Processor, located at utility computer center, request meter data from Data Logger, applies higher level error detection, punches correct data on paper tape for the billing computer, and types error data out on Fault Typewriter.

Experimental Automatic Meter Reading Systems

Manufacturer	Industrial Process Engineers, Newark, New Jersey
System Name	I.P.E. Home Meter Reader System (Method "B")
Acronym	----
Meter/ Encoder	Conventional watthour, gas, or water meters modified to encode four decimal digits in digital form. Method 2 encoding employed.
Data Set/ Coupler	Upon request, a transmitter sends out a serial binary pattern representing a meter reading. A customer identity verification code is also sent.
Data Channel	Telephone lines. Telephone company fault scanner is used for selectively and inaudibly "ringing" customer meters.
Interface/ Decoder	Dataphone Data Set, located at telephone exchange, immediately retransmits each meter reading received from the fault scanner, in digital form, to the utility central office via high speed telephone data lines.
Data Compiler	I.P.E. Primary Data Processor, located at utility computer center, receives meter data from fault scanner, applies low and high level error detection, punches correct data on paper tape for the billing computer, and types error data out on Fault Typewriter.

Experimental Automatic Meter Reading Systems

Manufacturer	Landis and Gyr, Inc., Elmsford, N.Y. (U.S. Representatives)
System Name	Automatic Remote Meter Reading System
Acronym	METRAGYR
Meter/ Encoder	Conventional watthour or gas meters modified with change-over contact (bi-stable mechanical switch) Method 1 encoder. Old register replaced with one with changeover contact. New register has dial readout. Fixed quantity adjustable from 3 - 20 KWH, or 10 m^3 gas. Requires interrogation 8-10 times in 24 hour period.
Data Set/ Coupler	Ripple signal generator consisting of series L-C circuit between secondary phase wire and neutral which is keyed at half the power network frequency when activated by ripple control signal. Replies from individual meters are spaced in time.
Data Channel	Electric power distribution system.
Interface/ Decoder	Meter reading signals decoupled from neutral on secondary side of large network distribution transformers. Decoupled readings are sent to utility central office via telephone lines. Receiver at central office converts ripple signal to square wave signals.
Data Compiler	Contact positions of Method 1 encoders are punched on paper tape for processing by billing computer. Central office equipment starts all meters located on a line with a ripple control signal.

Experimental Automatic Meter Reading Systems

Manufacturer	McGraw-Edison Co., Milwaukee, Wisconsin
System Name	Automatic Remote Meter Reading System (Version 1)
Acronym	ARMETER
Meter/ Encoder	Conventional watthour, gas, or water meters modified by attaching auxiliary dial position reading, Method 2, internal encoder to units shaft. Encoder represents up to 2560 KWH. Dials read photo-electrically. Original dials retained.
Data Set/ Coupler	McGraw-Edison transponder producing frequency multiplexed continuous meter reading signals and rest tone customer identity verification. McGraw-Edison d.c. alerted line coupler employed.
Data Channel	Telephone lines. McGraw-Edison coupling equipment and test and verification switch train used at telephone company central office.
Interface/ Decoder	McGraw-Edison Master Control and Data Terminal decodes frequency multiplexed tones and interfaces telephone lines with computer.
Data Compiler	Mini-computer, ASR33 teletype, paper tape reader, and paper tape punch.

Experimental Automatic Meter Reading Systems

Manufacturer	McGraw-Edison Co., Milwaukee, Wisconsin
System Name	Automatic Remote Meter Reading System (Version 2)
Acronym	ARMETER
Meter/ Encoder	Conventional watthour, gas, or water meters modified by attaching auxiliary dial position reading, Method 2, internal encoder to units shaft. Encoder represents up to 2560 KWH. Dials read photo-electrically. Original dials retained.
Data Set/ Coupler	McGraw-Edison transponder producing frequency multiplexed continuous meter reading signals and rest tone customer identity verification. A.T.&T. Co. Meter Reading Access Arrangement (MRAA) employed for coupler.
Data Channel	Telephone lines. Telephone central office is equipped with A.T.&T. Co. Meter Reading Access Circuit (MRAC).
Interface/ Decoder	A.T.&T. Co. X406C1 Data Communications Terminal (DCT) and McGraw-Edison frequency multiplexed tone decoder.
Data Compiler	Mini-computer, ASR33 teletype, paper tape reader, and paper tape punch.

Experimental Automatic Meter Reading Systems

Manufacturer	Neptune Meter Co., Wallingford, Conn.
System Name	Central Automatic Reading and Billing System
Acronym	CARB
Meter/ Encoder	Conventional watthour, gas, or water meters modified Neptune's Repeater, Encoder Index, or Encoder Register, respectively (dial position reading). Method 2, internal encoder encodes four decimal digits. Dials retained for visual reading.
Data Set/ Coupler	Transponder using three frequency, frequency shift keying (FSK) to transmit meter data. One out of ten code employed to represent decimal digits. In one variation, three meters may be serviced with one transponder. A four digit I.D. code is transmitted along with meter data. Coupler is A.T.&T. Co. Meter Reading Access Arrangement (MRAA).
Data Channel	Telephone lines. Telephone central office is equipped with A.T.&T. Co. Meter Reading Access Circuit (MRAC).
Interface/ Decoder	A.T.&T. Co. X406C1 Data Communications Terminal (DCT) and Neptune's Command Console containing a serial to parallel decoder.
Data Compiler	Utility's recorder, computer, or one supplied by Neptune.

Experimental Automatic Meter Reading Systems

Manufacturer	North American Research Corp., Rockville, Maryland
System Name	Utility Meter Remote Automatic Reading System
Acronym	UMRARS
Meter/ Encoder	Conventional or solid state watthour meter; conventional gas and water meters. Method 2 encoder counts revolutions of KWH meter discs with precounter. When watthour constant is reached, precounter feeds one KWH into counter/memory and resets to zero. Original dials retained on conventional meters. Counter/Memory will retain count in event of power failure.
Data Set/ Coupler	Interrogation Receiver containing digital discrete address authenticating circuitry. When addressed, Reply Transmitter sends out meter reading and identification code in binary form using pulse frequency modulation.
Data Channel	Electric power line distribution system. Wireless by-passes are used around each transformer in the system.
Interface/ Decoder	Interrogation Transmitter sequentially sends out digital discrete addresses of meters over the power lines. Pulse frequency modulation is used. The Interrogation Transmitter frequencies are different than the Reply Transmitter frequencies allowing addressing and reply to occur simultaneously.
Data Compiler	Billing computer used on-line or "Reply Store" consisting of magnetic tape stores.

Experimental Automatic Meter Reading Systems

Manufacturer	Praynor Industries, Tempe, Arizona
System Name	----
Acronym	----
Meter/ Encoder	Conventional watthour meter or solid state watthour meter with Method 2, internal, pulse counting encoder. Interrogation every 30-1/2 days.
Data Set/ Coupler	Meter data transmitted as binary strings to billing computer.
Data Channel	Telephone lines. Meter data transmitted from customer to billing computer and billing data transmitted back to bill producing "box" at customer residence.
Interface/ Decoder	Not described.
Data Compiler	Billing computer receives meter data, calculates usage and bill, and sends billing information to a unique device located at customer home which prints bill in triplicate. Customer keeps one copy and sends second copy with money to utility. Third copy remains on roll of bills. Five (5) year replaceable bill magazine supplied with each customer "box."

Experimental Automatic Meter Reading Systems

Manufacturer	Readex Electronics, Inc., Honeoye Falls, New York
System Name	----
Acronym	----
Meter/ Encoder	Conventional watthour, gas, or water meters modified for Method 2 encoding.
Data Set/ Coupler	Remote unit radio frequency receiver/transmitter. Receiver recognizes unique digital discrete address signal which initiates reply. Transmitter replies by sending meter reading in serial digital form. Phase reversal keying is used for the command signal and the reply.
Data Channel	Radio. Interrogation in an Industrial band from an aircraft flying at an altitude of approximately 40,000 ft.
Interface/ Decoder	Radio frequency transmitter and receiver located in an airplane. Transmitter sends out digital discrete addresses of meters; receiver receives and decodes meter data.
Data Compiler	Command Unit, located in the aircraft, gathers meter reading data and records this data on magnetic tape. The utility uses the magnetic tape for billing.

Experimental Automatic Meter Reading Systems

Manufacturer	Ripley Company, Inc., Middletown, Conn.
System Name	----
Acronym	----
Meter/ Encoder	Conventional watthour, gas, or water meters modified by attaching Method 2 encoder to tens dial position. Original dial retained.
Data Set/ Coupler	Ripley frequency multiplexed continuous signal data set with A.T.&T. Co. Meter Reading Access Arrangement coupler (MRAA).
Data Channel	Telephone lines. Telephone central office is equipped with A.T.&T. Co. Meter Reading Access Circuit (MRAC).
Interface/ Decoder	A.T.&T. Co. X406C1 Data Communications Terminal (DCT) and a Ripley frequency multiplexed tones decoder.
Data Compiler	Billing computer.

Manufacturer	Sangamo Electric Company, Springfield, Ill.
System Name	Public Utility Revenue Data Acquisition System
Acronym	PURDAX
Meter/ Encoder	Conventional watthour, gas, or water meters modified with single pole, double throw switch (pulse initiator). Dial face retained. External, binary, pulse counting, Method 2 encoders employed. Eight (8) pulse counters are located in one Data Accumulator package. Back-up re-chargeable batteries for continuation of counting during power outages.
Data Set/ Coupler	Unique passive, harmonic generating transponder, activated by continuous r.f. signal from interrogation van, transmits meter data at twice the interrogation signal frequency. Contents of Data Accumulator key the 2nd harmonic signal (on-off keying) in serial binary fashion. Identification are bits appended to meter data.
Data Channel	Radio. Very short range operation (less than 200 ft) in an Industraial band from a moving interrogation truck.
Interface/ Decoder	UHF transmitter and UHF receiver located in interrogation van.
Data Compiler	Decode and Verification Unit discards invalid data and records good data on magnetic tape.

Experimental Automatic Meter Reading Systems

Manufacturer	Westinghouse Electric Corp., Raleigh, N.C.
System Name	Total Computer Oriented Metering System
Acronym	T-COM
Meter/ Encoder	Conventional watthour, gas, and water meters modified with reed switch and magnet (pulse initiator). External, multiple, Method 2 encoder for three meters. Encoders up to 9990 KWH before recycling. Original dials retained.
Data Set/ Coupler	Three meter readings and identity verification bits are scanned out of the encoder in the form of a serial, binary bit train into an A.T.&T. Co. Residential Utility Meter Reading Data Set, X406A (MRD). The data set, operated in the serial mode, transmits data using two frequency FSK.
Data Channel	Telephone lines. Telephone central office is equipped with A.T.&T. Co. Meter Reading Access Circuit (MRAC).
Interface/ Decoder	A.T.&T. Co. X406C1 Data Communications Terminal (DCT) and a Westinghouse serial to parallel decoder.
Data Compiler	Westinghouse P-50 mini-computer, ASR35 teletype, and two magnetic tape drives.

Experimental Automatic Meter Reading Systems

Manufacturer	Zodiac Electronics Corp.
System Name	Unknown
Acronym	----
Meter/ Encoder	Conventional watthour, gas, and water meters modified by attaching potentiometer to hundreds position of dial. Internal, Method 2 encoding employed. Original dial retained.
Data Set/ Coupler	Data set consisting of circuit which closes relay which inserts potentiometer in circuit when a signal is sent over telephone lines. Subscriber cannot use telephone during interrogation.
Data Channel	Telephone lines. Unmodified telephone company central switching office.
Interface/ Decoder	Wheatstone bridge decoder measures impedance of selected telephone line, then sends signal which closes relay in customer data set. Decoder then measures impedance of line plus potentiometer.
Data Compiler	Manual. Meter reading is proportioned to difference in impedances.

VITA

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